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(54) Title: NANOSCALE PARTICLES, AND USES FOR SAME

(57) Abstract

Nanoscale particles and powders are made from a starting material, including larger-size starting particles and solid targets. Various techniques are disclosed all of which generally involve heating and decomposing the starting material with an energy source selected from the group consisting of laser, electric arc, flame and plasma. The various techniques disclosed herein all exhibit a high throughput and a nearly instantaneous rate of production of nanoscale powders for a variety of applications. In certain of the embodiments, cooling is required to prevent agglomeration of the nanoscale particles into larger (non-nanoscale) particles. The nanoscale particles are useful for painting, coating, joining, bonding, brazing, soldering, welding, etc. For example, thermal stresses normally associated with joining (e.g., brazing) may be alleviated by a low-temperature joining technique of the present invention. A low-temperature joining material is applied (as a paste, or as a powder spray, or as a tape, or as a paint, or as a putty) at the junction of two components desired to be joined together. Energy from a source such as a laser beam (for example an Nd:YAG or a CO_2 laser) or by a flame, arc, plasma, or the like, is either "walked" along the joining material to react the entire amount joining material, or the joining material is self-sustaining and simply requires igniting a selected portion of the joining material by the energy source. In an exemplary application of the process, vanes are brazed to the bowl and/or to the shroud of an automatic transmission bowl (impeller or turbine) assembly, preferably using the low-temperature joining material. Systems for delivering the joining material and the energy are described. The fabrication of hollow vanes is described. The fabrication of shroudless bowl components, and stator components subsuming the function of the shroud are described.

TITLE: NANOSCALE PARTICLES, AND USES FOR SAME

TECHNICAL FIELD OF THE INVENTION

This invention relates to techniques for fabricating (synthesizing) nanoscale particles, including CaO (calcium oxide), MgO (magnesium oxide), TiO_2 (titanium oxide), VO_2 (vanadium oxide), Al_2O_3 (alumina, or aluminum oxide), iron oxides (FeO, Fe_2O_3, Fe_3O_4), silicon oxide (SiO_2), Y_2O_3 (yttrium oxide) and other oxides, Au (gold), Cu (copper) and Zn (zinc), tin (Sn), lead (Pb), Silver (Ag), Silicon (Si), chromium (Cr), Cobalt (Co), iron (Fe) and other metals, BN, TiN and other nitrides, borides, ZnS and other sulfides, hydroxides, SiC, WC and other carbides, and other compounds, complex, composites and mixtures. The invention also relates to uses for nanoscale particles, and compositions containing same.

BACKGROUND OF THE INVENTION

A need generally exists for commercially producing nanoscale (ultrafine-grained, typically about 1-100 nm in grain diameter) materials on a large scale. Applications of nanoscale materials include treating military wastes, air cleaning, military personnel protection against chemical weapons, joining materials and bonding materials. Properties (characteristics) of nanoscale materials include large surface area (e.g., relative to volume), high reactivity, low melting point, and utility as catalysts. For example, nanoscale copper materials (particles, powders) can be melted at significantly lower temperatures than larger copper particles.

A commensurate need exists for commercially producing nanoscale material for use in Destructive Absorption Technology (DAT). DAT, a non-polluting treatment process, is used for treating hazardous substances, including military relevant

chemical and wastes, chlorocarbons, organosulfide, organophosphorus (model compounds of nerve agents) compounds, and contaminated soil and debris while allowing reclamation of valuable byproducts as fuels or feedstocks.

DAT performance is dependent upon the synthesis and use of ultrafine (nanoscale), highly reactive metal oxides (e.g., CaO or MgO) as destructive adsorbents.

Although research on nanoscale materials is relatively recent, it has been experimentally demonstrated that nanoscale particles possess many unique properties, such as extremely large surface area, significantly lower melting points, novel mechanical, thermal, optical, magnetic, electronic and chemical characteristics. Moreover, these properties are often improved over those of conventional coarse-grained (i.e., non-nanoscale) materials for many applications. The large surface area is a critical property for chemical and physical adsorption, catalysis and many chemical reactions. Greatly enhanced chemical reactivity has been demonstrated with nanoscale materials.

Nanoscale materials have become a significant part of new materials synthesis, having a broad range of applications. Extraordinary properties have been found in nanoscale materials. For example, melting temperature of CdS and gold nanocrystals drop by 1000°K when crystallite sizes decrease from 50 nm (nanometers) to 10 nm. Microhardness of nanoscale copper increases by a factor of 5 as grain size changes from 50 micrometer to 6 nanometer. Catalytic and normal chemical activities is greatly enhanced. Ionic conductivity can be increased by a order of magnitude over single crystal materials. Optical absorption also changes.

Prior art methods for preparation of nanoparticles include chemical or physical vapor deposition, sol-gel processing, gas condensation, electrolytic deposition, inverse micelles technique, layer-by-layer growth, microphase-separated reaction, electrostatic spraying, mechanical alloying, and laser

photolysis. However, due to intrinsic chemical properties of many materials (e.g. calcium and magnesium), they are not commercially feasible for the preparation of nanoscale materials.

In one prior art technique, a gas is heated to a high temperature, then condensed to obtain nanoscale materials.

In another prior art technique, a sol or gel is baked at a high temperature, including sometimes at a high pressure (autoclaved). This type of technique is expensive and time-consuming. The process can take several days or weeks. The quality of the resulting nanoscale material tends to be poor (e.g., poor control over particle size). The process exhibits a low throughput, and is limited to producing a narrow range of nanoscale materials (e.g., CaO and MgO), and is not useful for the production of other materials (e.g., Cu, or any metal nanoscale material).

Excellent results have been obtained in the laboratory with specially prepared (by aerogel/hypercritical drying) metal oxides. (see K.J. Klabunde, Free Atoms, Clusters, and Nanoscale Particles, Academic Press: San Diego, 1994; Y.Li, O.Koper, M. Atteya, K.J.Klabdune, Chemistry of Materials 4 (2), 323 (1992); Y.Li, K.J.Klabunde, Langmuir 7 (7), 1388 (1991); M. Atteya, K.J. Klabunde, Chemistry of Materials 3 (1), 182 (1991). Using organophosorous compounds as model nerve agents or chemical agent stimulants, e.g. dimethyl methyl phosphonate (DMMP) and an in-situ micro-reactor GC-MS system, it has been demonstrated that the organophosphorus model compounds can be completely decomposed by ultrafine nanoscale MgO powder. While other products, including formic acid, water, alcohols, alkenes, CO and methane evolved upon formation, phosphorous residues retained on MgO powder permanently. As predicted on the basis of surface area, they experimentally proved that smaller nanoscale MgO crystallites exhibited higher chemical reactivity. However, the process of making the powder is expensive and time consuming.

U.S. Patent No. 5,128,081, incorporated by reference herein, discloses a method of making nanocrystalline alpha alumina (Al_2O_3).

U.S. Patent No. 4,910,155, incorporated by reference herein, discloses uses (e.g., wafer flood polishing) for SiO_2 particulates having an average size of 0.006 microns.

Additional references of interest include Offenlegungsshrigt 25 23 049, Japanese No. 2-30705, U.S. Patent No. 4,619,691, U.S. Patent 4,556,416, and U.S. Patent No. 4,289,952.

Among the shortcomings of prior art techniques for making nanoscale materials is that they are both time consuming and expensive. What is needed is a cost and time effective method for making nanoscale materials.

Another aspect of the invention is related to using nanoscale materials to join (e.g., braze) components to one another, and is discussed in greater detail hereinbelow.

Joining metal components to one another, in a manner resembling brazing or soldering, and is particularly well suited to joining components of an automatic transmission such as the impeller or turbine thereof.

It is generally well known to assemble components (workpieces) together by mechanical instrumentalities such as nuts and bolts, rivets, tabs and slots. For example, with respect to tabs (also known as "lugs" or "pawls") and slots (also known as "slits", "recesses", "grooves" or "indentations"), it is known to assemble blades (also known as "vanes") having tabs on their outer edges to an outer shell (also known as "bowl") of an automotive automatic transmission torque converter impeller or turbine (also known as a "vane wheel", jointly referred to herein as "bowl assemblies") having slots extending into or through its inner surface into which the tabs fit. Similarly, it is known to assemble an inner shroud component (also known as "core tube" or "torus ring") to the inner edges of the vanes by fitting tabs on the inner edges of

the vanes through slots extending through the inner shroud component, then bending over the tabs. The use of tabs and slots, to assemble vanes to the bowl and shroud of an automatic transmission impeller assembly is shown, for example, in U.S. Patent No. 3,782,855 (the "855 patent), and in U.S. Patent No. 4,868,365 (the "365 patent"), incorporated by reference herein. The following paragraphs emphasize certain problems attendant assembling vanes in a bowl of an automatic transmissions.

The "855 patent" discloses a vane wheel for fluid couplings or torque converters, especially for motor vehicles. As disclosed therein, a plurality of vanes are disposed between two toroidal surfaces, an outer toroidal surface (e.g., a torque converter shell) and an inner toroidal surface (e.g., a torque converter shroud). As noted in the "855 patent" the individual vanes have significant flexibility and, during abrupt changes in transmitted torque, the inner toroidal surface (i.e., the shroud) tends to displace itself angularly (e.g., rotate), vis-a-vis the outer toroidal surface (i.e., the bowl). The solution proposed in this patent is to provide separate and distinct (i.e., from the vanes 12) anti-rotational bracing members (plates 20) extending from the outer toroidal surface to the inner toroidal surface. These plates (20) are fixed by welding or soldering to the toroidal surfaces. In an embodiment of the "855 patent", the anti-rotational bracing members are formed as right-angle bent portions (30) at the ends of certain vanes (12), and these bent portions are advantageously force-fitted between the toroidal surfaces. In a further embodiment, bent portions (30) are formed facing one another on two adjacent vanes (12) and are connected by a bar (35) which is fixed to the bent portions and to the toroidal surfaces by welding, brazing or soldering.

A non-trivial problem in the fabrication and usage of vaned-impellers (or turbines) such as in automotive torque converters (e.g., the impeller assemblies thereof) is leakage (of fluid) occurring between the blades (vanes) and the toroidal

surface of the bowl. Generally speaking, leakage will result in decreased fluid dynamic (hydrodynamic) efficiency which, in the context of an automotive torque converter, will translate into reduced gasoline (fuel) efficiency.

U.S. Patent No. 5,282,362 (the "362 patent") discloses a technique for sealing (reducing leakage) involving the use of elastomeric linings on the core and shell surfaces, proximate the blades. The elastomeric linings are deformed where the blades engage the core and shell surfaces. This localized deformation effects a seal between the core and shell surfaces, which eliminates leakage between the cores and the shells, thereby increasing torque converter efficiency.

Returning to the challenge of affixing a plurality of vanes (blades) to a toroidal surface (especially the outer housing of a torque converter), there has been limited effort, in recent years, directed to welding the vanes into the bowl. For example, U.S. Patent No. 4,868,365 (the "365 patent"), entitled METHOD FOR WELDING TORQUE CONVERTER BLADES TO A HOUSING USING A LASER WELDING BEAM, discloses forming blades (vanes) with a tab fitted within a recess formed in the impeller housing (bowl) such that the blade stands clear of the adjacent surfaces of the housing by the width of an air gap. A laser beam is directed onto an adjacent surface of the housing a short distance from an edge of the housing adjacent a blade tab to be welded to the housing. A laser beam whose axis is inclined with respect to the recess, strikes a surface of the housing adjacent the tab. The welding (e.g., laser) beam is moved parallel to the blade tab so that the blade tab is welded to the housing, without the use of filler material. The housing is rotated to bring successive blade tabs into position for welding.

As is evident, the technique of the "365 patent" amounts to "spot" (localized) welding of the blades to the bowl, and does not address the leakage problem addressed hereinabove. Moreover, in any process, such as those mentioned above, for affixing a plurality of blades to an automatic transmission

impeller housing, involving the use of slots in the impeller housing, in order to affix a different number or shape of blades to the bowl, or to affix the same (or a different) number of blades to the bowl at a different angle, it is necessary to modify the slot configuration (e.g., number, spacing, angle) of the bowl.

U.S. Patent No. 5,109,604 (the "604 patent"), incorporated by reference herein, discloses a method of assembling a torque converter impeller assembly showing traditional tab/slot assembly of the inner edges of the vanes to a semitoroidal core ring, and a technique of assembling the vanes and core ring, as a subassembly, to the interior surface of the outer shell (bowl). Figure 4 of the "604 patent" illustrates the process of fixturing (see fixture 39) the vanes for assembly of the core tube (via tabs and slots) to the inner edges of the vanes to fabricate the subassembly. A brazing material is applied to the outer (towards the bowl) edges of the vanes (as well as along the edges of the bent tabs on the inner edges of the vanes). The subassembly of the core ring and vanes, with brazing material applied thereto, is then positioned in the outer shell (bowl). The outer shell, vanes and core ring are then disposed in a brazing oven whereby the braze metal (e.g., paste) flows along the outer edges of the vanes (as well as along the edges of the inner tabs of the vanes), to securely bond the vanes to the outer shell (as well as to complete the bonding of the core ring to the vanes). The advantages of this technique for assembling the vanes to the bowl, cited in the "604 patent" include:

(a) the vanes need not be aligned with special indentations in the bowl, thereby facilitating the assembly of the torque converter impeller; and

(b) since the outer shell (bowl) does not require indentations (slots), it is not necessary to inventory outer shells by the orientation of the indentations in the outer shell. Outer shells can be used with a variety of vanes , and

it is easier to change from one vane configuration to another vane configuration.

Irrespective of the particular milieu of affixing vanes to the bowl component of an automatic transmission, brazing is a generally well known technique of joining components (e.g., two articles, two workpieces) to one another and generally involves melting (i.e., causing a thermal reaction in) a brazing material (also referred to as a "filler material") at temperatures of approximately 1000°C (one thousand degrees Celsius). The brazing material (typically in paste form) may be the same as or different in composition from than the material of the to-be-joined components. As distinguished from welding, brazing typically does not involve the melting of the components being joined together, and welding does. (See, e.g., the "365 patent" which describes a welding beam melting a component being joined, and subsequent flow of the molten material.) Melting the components being joined together (as in welding) affects the grain orientation of the components, as well as any temper that may have been imparted to the component(s). Irrespective of whether a technique is classified as brazing or welding, the use of high temperatures can cause undesirable distortion, annealing, or the like of one or both of the components (workpieces) being joined together.

Disposing a torque converter impeller in a brazing oven, as disclosed by the "604 patent", is particularly problematic, as it will result in "mass" (overall) heating of the components being assembled, as well as in distortion of the components. Such mass heating of the torque converter bowl is detrimental to the metallurgy of the bowl which may, for example, already have been provided with a hardened hub which will lose its temper as a result of such mass heating. Moreover, it is evident that a component heated in an oven to sufficient temperatures to effect brazing will require a significant, and in some cases controlled, cooling-off period.

U.S. Patent No. 3,673,659 (the "659 patent"), entitled METHOD FOR BONDING VANES IN [A] TORQUE CONVERTER, describes previous attempts at bonding vanes to a slotless impeller bowl by brazing, using a brazing paste which is a mixture of pulverized copper and alcohol, in an electric furnace. The method described in this patent involves temporarily connecting the vanes to the core ring by spot welding, then fitting this subassembly of vanes/core tube to the bowl. (This pre-fabrication of a subassembly, comprising vanes joined to the core tube, for insertion as a unit into the bowl, is analogous to that of the aforementioned "604 patent"). Brazing material, in the form of copper rings (13a, 13b, 13c, 13d), is disposed between flanges (10a, 10b) on the vanes (10) and each of the core tube (11) and the bowl (12). Then, the to-be-brazed assembly is placed in an electric furnace which is filled with a suitable reducing atmosphere and is internally maintained at a temperature ranging from 1,110°C to 1,130°C to heat the assembly at a temperature higher than the melting point of the copper rings. The thermal cycle discussed in the "659 patent" is preliminary heating for 18 minutes (until the desired temperature is attained), maintaining the desired temperature for 10 minutes, and slowly cooling down the assembly for 54 minutes - a process taking approximately one and one half hours to achieve the sought after brazing of vanes. There is no suggestion in this patent that the resulting brazed joints are more than localized to the position of the copper rings (e.g., resulting in an analogue of spot-welding the vanes).

Further attention is directed to U.S. Patent No. 4,833,295 (the "295 patent"), entitled WELDING OF PARTS SEPARATED BY A GAP USING A LASER WELDING BEAM, which discloses a related technique for welding together two portions of a cover for a torque converter at an overlap joint using a welding beam.

Another phenomenon attendant automatic transmission bowl assemblies (impellers, turbines) is that the bowl component tends to "balloon" in response to the fluid pressures contained

therein. This, of course, exacerbates the any pre-existing leakage (i.e., between the vanes and the bowl) problem, since any gap between the vanes and the bowl will grow as the bowl balloons. Additionally, it is intuitively evident that such ballooning of the bowl imposes undesired stresses on the bowl and on any means of joining the vanes to the bowl, and that enhanced bowl stiffness (resistance to ballooning) would be desirable.

SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide an improved technique for making nanoscale materials.

It is a further object of the present invention to provide a technique for making nanoscale destructive adsorbent particles

It is a further object of the present invention to provide a technique for making CaO or MgO nanoscale destructive adsorbent particles.

It is a further object of the present invention to provide a technique for making CaO or MgO nanoscale destructive adsorbent particles, and using same for destroying hazardous chemicals.

According to an aspect of the invention, various techniques are disclosed for producing nanoscale particles from a starting material (e.g., gases, solid, liquid, or solid/liquid mix. Generally, the various techniques all involve heating and decomposing the starting material with at least one energy source selected from the group consisting of laser, electric arc, flame and plasma. In certain instances, cooling is required to prevent agglomeration of the nanoscale particles into larger particles. The various techniques disclosed herein all exhibit a high throughput and a nearly instantaneous rate of production of nanoscale particles for a variety of applications.

The invention is useful for producing nanoscale particles that include: oxides, carbides, borides, nitrides, sulfides,

hydroxides, metals, alloys, compounds, complex, and composites.

According to a first embodiment of the invention referred to herein as "laser decomposition", a laser is directed at and ablates a target to produce nanoscale powders such as oxides from starting materials such as carbonates and hydroxides.

The following exemplary nanoscale powders can be made using this laser ablation technique:

- to make CaO, direct the laser at a target formed of calcium carbonate or calcium hydroxide;
- to make Al_2O_3, direct the laser at a target formed of aluminum hydroxide;
- to make MgO, direct the laser at a target formed of magnesium carbonate or hydroxide.

Such nanoscale powders (oxides) are useful, inter alia as destructive adsorbents for military chemical wastes or as air purifiers.

According to an aspect of this embodiment of the invention, a carrier gas may be used to carry the nanoscale powder away from the target to a collector which is formed to separate nanoscale particles from larger-size particles. The carrier gas may be an oxidant (contain oxygen) or, in the case of making metal nanoscale powders may be a non-oxidizing gas such as nitrogen.

The carrier gas/gases may also act as a reactant/reactants (e.g., N_2 in the process of forming nitride; O_2 in the process of forming oxide, etc.) .

According to a second embodiment of the invention referred to herein as "arc heating", an electric arc decomposes a starting material (e.g., larger-size carbonates and hydroxides) into nanoscale particles (e.g., nanoscale oxide particles).

According to an aspect of this embodiment of the invention, large particles of a starting material (e.g., carbonates and hydroxides) are conveyed along a path that is exposed to an electric arc which decomposes the starting material into the sought after nanoscale powder.

In a variation of this embodiment, a coolant such as liquid nitrogen may be required to agglomerate the too-small particles into nanoscale particles] prevent agglomeration of nanoscale particles into larger particles.

According to a third embodiment of the invention referred to herein as "high temperature flame spray", the starting material is introduced through a nozzle, such as the nozzle of a flame torch. An appropriate fuel (e.g., oxygen and one of acetylene, propane, propene, hydrogen, or the like) is also directed through the nozzle. A flame at the end of the nozzle decomposes the starting material into an associated nanoscale powder (e.g., calcium carbonate starting material decomposes into calcium oxide), which is directed (and cooled) by compressed gas (e.g., compressed air) at a collector (bin). The apparatus may be arranged so that byproducts of the decomposing reaction (e.g., carbon dioxide gas) simply rise away from the bin.

According to an aspect of this embodiment of the invention, the temperature of the flame is controlled to ensure decomposition of the starting material. For example, to decompose calcium carbonate, the temperature should be maintained at a level of at least 825°C (degrees Celsius).

According to a fourth embodiment of the invention referred to herein as "high temperature plasma spray", in a manner similar to the third embodiment, the starting material is introduced through a nozzle similar to the nozzle of a flame torch. Instead of a fuel creating a flame for heating (decomposing) the starting material, a plasma is induced at the end of the nozzle, and heat from the plasma is transferred to the starting material by a heat-transferring medium, such as argon.

According to this embodiment of the invention, techniques for inducing the plasma include electric arc, laser, microwave, RF, hot filament, as well as other power transmitting sources such as x-rays, neutrons, etc.

This embodiment is similar to the third embodiment in that the nanoscale particles are directed by compressed gas (e.g., compressed air) at a collector (bin), and byproducts of the decomposing reaction (e.g., carbon dioxide gas) are separated by simply rising away from the bin.

The present invention provides an inexpensive, practical, and portable technique and system for making large amounts of nanoscale materials.

The present invention provides a technique for making nanoscale materials useful for painting, coating, joining, bonding, brazing, soldering and welding. Certain nanoscale materials produced by the present invention may also be useful in insect repellents.

Another aspect of the present invention is using nanoscale materials, such as those created by the techniques disclosed herein, in compositions useful for joining (e.g., brazing) together components.

It is a general object of this aspect of the present invention to provide an improved technique for joining any two (or more) components (workpieces) together (to one another).

It is another object of the present invention to provide a low mass temperature technique for joining any two (or more) components to one another.

It is another object of the present invention to provide an improved technique for assembling an automatic transmission impeller or turbine assembly (either of which is termed a "bowl assembly").

It is another object of the present invention to provide a technique for assembling a plurality of vanes to a bowl (component) of an automatic transmission bowl assembly that provides enhanced sealing of fluids being impelled by the vanes (or, vanes being impelled by fluids, in the case of a turbine assembly).

It is another object of the present invention to provide a technique for assembling a plurality of vanes to a bowl of an

automatic transmission impeller or turbine assembly that provides enhanced rotational stability between the bowl component and the shroud, directly via the vanes, without requiring additional anti-rotational bracing members.

It is another object of the present invention to provide a technique for assembling a plurality of vanes to a bowl of an automatic transmission bowl assembly that provides for mounting (affixing) a different number (or shape) of vanes, and/or affixing the vanes at a different angle, in the same bowl, without modifying the bowl itself (e.g., a slot configuration on the inner surface of the bowl component).

It is another object of the present invention to provide a technique for assembling a plurality of vanes to a bowl of an automatic transmission bowl (impeller or turbine) assembly that provides for the increased bowl stiffness (resistance to ballooning), without modifying the bowl itself.

According to the invention, a first component (or, a plurality of first components) is joined to a second component using a joining material (delivered in the form of a paste, a powder, a glue-mixture, via a tape carrier, etc.) that preferably can be melted at temperatures lower, preferably much lower, than the melting point of the components being joined. An energy source such as a laser (alternative energy sources are described hereinbelow) reacts (e.g., melts) the joining material.

As used herein, the term "joining material" refers to a composition of material, for example a mixture of particulate elements (ingredients) in a form such as a paste, a slurry, an aerosol (e.g., deliverable in a manner similar to paint), a tape, a ribbon, or the like which reacts (e.g., melts, fuses, and the like) when an energy source (such as a beam from a laser, or a spark, an arc, a heat source such as a flame from a cigarette lighter, or the like) is directed thereat. Moreover, the term "joining", as used herein, refers to the joining of components (workpieces, and the like) by means other

than mechanical means.

According to a feature of the invention, a laser (having a selected spot size) can be scanned over an "amount" (e.g., mass) of joining material (which is larger than the spot size) to react the joining material in its entirety. For example, the amount of joining material may be in the form or configuration of a layer, an elongated strip, or the like. Typically, for joining edges of two components, the configuration would be a strip.

According to a feature of the invention, a laser can be employed to initiate the reaction of a "self-sustaining" amount (or other form) of joining material, as described in greater detail hereinbelow.

In an embodiment of the invention, the first component is a vane (blade) joined to the inner, toroidal surface of an automatic transmission impeller bowl, or the like (e.g., an automatic transmission turbine bowl), and the vanes are joined to the bowl with or without (preferably without) the use of tabs (on the vanes) or slots (in the bowl).

According to a feature of the invention, an amount of joining material is applied along the entire length of a joint between the two components sought to be joined. With respect to joining vanes to an automatic transmission bowl, leakage between the vanes and the bowl will be minimized, thereby improving the fluid dynamic efficiency of the automatic transmission. Moreover, the vanes, securely affixed to the bowl by the techniques of the present invention, will act as stiffeners (ribs) to limit the outward expansion (ballooning) of the bowl.

According to a feature of the invention, a plurality of vanes are brazed to an automatic transmission bowl component using automated equipment (computer-controlled positioning mechanism) to place any number of vanes in the bowl at any desired angle, without requiring modification of the bowl itself.

In an embodiment of the invention, the joining material is formed of a material that, once a portion (e.g., an end, an intermediate portion, etc.) of the amount of joining material is "lit" (initiated, ignited) by the laser energy, will react exothermally to sustain (self-sustain) a reaction (e.g., melting) of the entire amount of the joining material. For example, the joining material contains nanoscale (≤100 nm size) particles of aluminum (Al) or magnesium (Mg). Nanoscale-size particles of aluminum are more readily available than nanoscale-size particles of magnesium.

According to an aspect of the invention, a low-temperature joining material (e.g., paste, powder) contains nanoscale (≤100 nanometer) size particles (elements, ingredients) of aluminum, magnesium, gold, cadmium, copper, zinc, tin, lead, silver, silicon, chromium, cobalt, antimony, bismuth, iron, carbon, boron, and alloys and composites of these materials. The nanoscale materials are suitable to react (e.g., melt) at temperatures of no greater than 400°C (e.g., 200-400°C). Preferably, the joining material contains sufficient amounts of exothermic material (e.g., nanoscale size particles of aluminum and/or magnesium) to be self-sustaining, once its reaction is initiated (e.g., by a laser beam).

For joining materials that do not contain nanoscale-size components, such as joining material containing 1-3 μm size particles (components) the melting temperature of such joining materials will inevitably be higher than 400°C.

According to an aspect of the invention, an energy beam such as a laser beam (for example provided by an Nd:YAG laser, a CO_2 laser, or other lasers, preferably operating in the infrared range), flame, arc, plasma, spark or the like, is "walked" (scanned) along the joining material, which is applied to a junction between two components to be joined. Preferably, a laser is used to react (melt) and/or to initiate (ignite) the joining material (which may be in the form of a paste, a powder, a tape, a glue or a putty), due to the ability to control the

spot size of a laser, direct the beam with automated equipment, control the depth of penetration into the workpiece (component being brazed), and the like. Generally, in the self-sustaining embodiment, wherein a laser (e.g.) is used to initiate a self-sustaining joining material, penetration into the workpiece is not an issue.

In an embodiment of the invention, a plurality of vanes are brazed to the bowl component (i.e., the impeller or turbine bowl) and optionally to the shroud of an automatic transmission impeller assembly, preferably using a low-temperature joining material (e.g., in powder or paste form) containing nanoscale (≤100 nanometer) size particles of aluminum, gold, cadmium, copper and/or zinc, cobalt, iron, nickel, silicon, and the like.

In a preferred embodiment of the invention, an Nd:YAG laser having a 200 W (Watt) output, emitting pulses of 0.5 ms (millisecond) duration at a frequency of 260 Hz (Hertz), with a beam diameter of approximately 1.5 mm (millimeters) is scanned over an amount of joining material (in the form of an elongated strip having a length of approximately two inches) in less than one second.

Generally, the beam has a diameter less than three millimeters, preferably between one and two millimeters. In the case of a non-circular beam, the "diameter" would be a linear cross-sectional dimension.

Generally, for purposes of reacting (and/or initiating) a joining material, it is preferred to use an infrared laser for its ability to generate heat, rather than to use an ultraviolet laser which would tend to ablate a material.

In an alternate embodiment of the invention, an Nd:YAG laser having a 500 W (Watt) output, emitting pulses of 1.0 ms (millisecond) duration at a frequency of 260 Hz (Hertz), with a beam diameter of approximately 1.5 mm (millimeters) is scanned over an amount of joining material (in the form of an elongated strip having a length of approximately two inches) in less than one second.

In a preferred embodiment of the invention, a self-sustaining joining material contains the following amounts, by weight, of the following materials, of the following particle size: 2% Cerium (<1μm); 3% Boron (<1μm); 5% Chromium (<1μm); 12% Nickel (<1μm); 18% Magnesium (1-3 μm, nanoscale if available); 15% Aluminum (nanoscale); 2% Tin (1-3μm); 5% Zinc (1-3μm); 20% Copper (1-3μm); and 18% Silver (1-3μm). (As is evident, these percentages are approximate, having been rounded off to the "ones" place, and total 101%). Other (e.g., alternative) recipes of ingredients for joining materials are described in greater detail hereinbelow.

The techniques of the present invention are also useful for joining components other than vanes and bowls, such as two flat plates together.

For example, in a "hemming" operation, a first plate extends beyond the edge of a second plate, and the extending edge of the first plate is folded back around the edge of the second plate. An elongated strip of joining material is applied along the length of the overlapping edge of the first plate, and joining is initiated by laser energy, either by scanning the laser beam along the elongated strip of joining material, or by initiating the reaction at a selected position (e.g., the end, the middle) along the elongated strip of joining material.

For example, self-sustaining joining material is applied as a layer between two flat plates, and joining is initiated at an exposed edge of the paste layer.

According to another aspect of the invention, vanes for automatic transmission bowl components (impeller, turbine) are formed as hollow members. Such hollow vanes are more rigid than flat (monolithic) vanes, and enhance the ability of the bowl component to be assembled without a shroud stabilizing the inner edges of the vanes. It is within the scope of this invention that flat (non-hollow) blades are assembled in a bowl component without a shroud. In any case, the present invention clearly contemplates a "shroudless" automatic transmission bowl

assembly.

According to another aspect of the invention, shroudless bowl assemblies (impeller, turbine) of automatic transmissions allow for stator components to be fabricated which will perform the function of the shrouds, and which may be designed to enhance and/or alter the fluid dynamics of the torque converter (fluid coupling). In this aspect of the invention, vanes are secured to the bowl components of an automatic transmission without shrouds (e.g., core rings, torus rings), preferably by the technique of low-temperature joining, preferably using self-sustaining joining materials, as discussed hereinabove. A stator component of larger overall diameter extends into an otherwise "dead" zone (i.e., the radial zone previously occupied by the shrouds), wherein fluid passage from the impeller to the turbine (and vice-versa) would otherwise be impeded (directed, divided, delineated, diverted) by one or both of the shrouds, and a peripheral region of the stator subsumes the function of directing hydraulic fluid from the impeller, around a peripheral zone of the torque converter, to the turbine. This permits "tailoring" the dead zone to achieve configurable performance of the automatic transmission by modifying the stator component, without modifying the bowl (impeller, turbine) assemblies.

In one embodiment of the invention, the stator component has an annular (toroidal) ring disposed about its periphery, the annular ring being of similar size and radius to the shroud components that it "replaces".

In another embodiment of the invention, the stator component is provided with a disc like ring, disposed about its periphery and aligned radially, extending into the dead zone otherwise occupied by the shroud components. This permits the vanes of the bowl component assemblies to be larger, extending (axially) nearly to the peripheral disc of the stator.

In either embodiment, by eliminating the shrouds (each shroud is a partial torus ring), the flow-directing function of the shrouds (e.g., of the annular ring formed by the opposing

shrouds on the impeller and turbine assemblies) is "subsumed" by the stator assembly.

Other objects, features and advantages of the invention will become apparent in light of the following description thereof.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic diagram of a laser ablation technique for making nanoscale particles, according to the present invention.

Figure 2A is a schematic diagram of an arc heating technique for making nanoscale particles, according to the present invention.

Figure 2B is a schematic diagram of another arc heating technique for making nanoscale particles, according to the present invention.

Figure 3A is a schematic diagram of a high temperature flame spray technique for making nanoscale particles, according to the present invention.

Figure 3B is a schematic diagram of a high temperature plasma spray technique for making nanoscale particles, according to the present invention.

Figure 4A is a cross-sectional view of an automatic transmission bowl (e.g., impeller) assembly of the prior art.

Figure 4B is an exploded, partial perspective view of the automatic transmission bowl assembly of **Figure 4A**.

Figure 5A is a perspective view of two components (workpieces) brought together for joining, according to the present invention.

Figure 5B is a perspective view of the two components of **Figure 5A**, with a joining material disposed at the junction of the two components, according to the present invention.

Figure 5C is a perspective view of the two components of **Figure 5B**, with an energy beam directed at the joining material,

according to the present invention.

Figure 6 is a cross-sectional view of an automatic transmission bowl (e.g., impeller) assembly that has been assembled according to the techniques of the present invention.

Figure 7 is a cross-sectional view of an embodiment of a nozzle for delivering joining material simultaneously with applying an energy source, according to the present invention.

Figure 7A is a cross-sectional view of an alternate embodiment of delivering joining material simultaneously with applying an energy source, according to the present invention.

Figures 8A and 8B are flattened, and folded (assembled) views, respectively, of a technique of forming a hollow turbine blade, according to the present invention.

Figures 8C and 8D are pre-flattened and flattened views, respectively, of another technique of forming a hollow turbine blade, according to the present invention.

Figure 9 is a stylized cross-sectional view of an automatic transmission having an impeller, a turbine and a stator, according to the prior art.

Figure 9A is a cross-sectional view of a portion of an automatic transmission having an impeller, a turbine and a stator, according to an embodiment of the present invention.

Figure 9B is a cross-sectional view of a portion of an automatic transmission having an impeller, a turbine and a stator, according to an alternate embodiment of the present invention.

Figure 10A is a cross-sectional view of a technique for joining two components by "hemming", according to the present invention.

Figure 10B is a cross-sectional view of a technique for joining two components by "laminating", according to the present invention.

Figure 11A is a cross-sectional view of a two-part tape for delivering joining material, according to the present invention.

Figure 11B is a cross-sectional view of a three-part tape

for delivering joining material, according to the present invention.

DETAILED DESCRIPTION OF THE INVENTION

As used herein, the terms "nanoscale material(s)", "nanoscale particle(s)", or "nanoscale powder(s)" have the same meaning and may be used interchangeably, and are intended to include truly 'nanoscale' materials (particles having sizes less than or equal to 100 nanometers(nm)) as well as 'submicron' materials (particles having sizes greater than 100 nm, but less then or equal to 1 micron (μm)).

As used herein, the term "starting material(s)" includes metals, oxides, carbides, borides, nitrides, hydroxides, carbonates, sulphides, sulphates, chlorides, alloys, composites, complex, and mixtures. The starting material may be in the form of a gas, liquid, solid/liquid mix (paste), or solid.

As used herein, the term "coolant mechanism" refers to a medium (such as a gas, liquid or solid) which is used to prevent agglomeration ("trapping") of the decomposed (from starting material) nanoscale particles. The requirement for using the coolant mechanism will be determined by the structure of the nanoscale material. Coolant gases includes compressed air and nitrogen, etc.; coolant liquid includes liquid nitrogen, etc.; coolant solid includes dry ice, etc. Coolant medium includes a heat sink (for absorbing heat and trapping the particle). In the case of metals (e.g. gold and Cu), the particles do not agglomerate as easily and therefore a coolant mechanism may not be necessary.

A "carrier gas" may be employed to transfer the nanoscale material to a collector; the use of a carrier gas may depend on the alignment and configuration of the system.

In each of the following embodiments, the setup may be aligned to optimize the process (e.g., eliminating the need for a carrier gas to transfer nanoscale particles to a collector

bin). The relative orientation of the laser, starting material, and collector bin can modified or changed. Also, the carrier gas and coolant gas may, in certain cases, be the same.

LASER DECOMPOSITION

Figure 1 illustrates a system 100 for making (fabricating, synthesizing) nanoscale particles (powder) by laser ablation. A laser beam 102 is directed at a surface 104 of a target 106 (starting material) to ablate "source" material from the target. The ablated material (108, 110) will contain both nanoscale particles (powder, shown as small dots) 108 and larger-size particles (shown as large dots) 110. The ablated material (108, 110) is directed by a stream of carrier gas 112 supplied from a tube (pipe, or the like) 114 which traverses (from left-to-right, as viewed) the surface 104 of the target 106. The ablated material (108, 110) is carried by the carrier gas 112 towards an inlet (opening) 116 of a collector system 118. The collector system 118 performs the function of separating the larger-size particles 110 from the nanoscale powders 108.

The collector system 118 is provided with a first reservoir 120 immediately adjacent the inlet 116. The first reservoir 120 extends laterally (from left-to-right, as viewed) to ensure that the heavier (massier), larger-size particles (110) will have an opportunity to drop out (downward, as viewed, by action of gravity) of the stream of carrier gas prior to the stream of carrier gas reaching an outlet opening 122 of the first reservoir 120. Smaller, lighter particles, namely the nanoscale powders (108) will continue to be carried by the carrier gas through the outlet 122 of the first reservoir 120. Based on the known sizes of the ablated target material (108, 110), the flow of the carrier gas and the dimensions of the first reservoir are readily established to effect this desired result.

The nanoscale powders (108) are conveyed by the carrier gas through a channel 124 into a collection section 126 of the collection system 118. The collection section 126 is

essentially a vertically-oriented pipe (tube) open at both ends and communicating with a distal (right, as viewed) end of the channel 124. The proximal (left, as viewed) end of the channel 124 is adjacent the outlet 122 of the first reservoir 120.

A second reservoir 128 is disposed at the bottom end of the collection section 126 so that the nanoscale powders (108) will drop (downward, as viewed, by action of gravity) into the second reservoir 128. To this end, the vertically-oriented pipe of the collection section extends sufficiently above the channel 124 to ensure that substantially all of the nanoscale powders have an opportunity to drop downward into the second reservoir. Generally, the carrier gas is simply vented out of the top of the collection section. The flow rate of the carrier gas is controlled to effect the desired result.

The collection system 126 has been illustrated with two reservoirs in series - a first reservoir 120 collecting larger (heavier) particles and the second reservoir 128 collecting smaller particles (i.e., nanoscale powders). It is certainly within the purview of one having ordinary skill in the art to which the present invention most nearly pertains to provide additional (i.e., more than two) reservoirs, connected in series by additional channels, so that a gradient of particle sizes can be collected (e.g., from large-to-medium-to-small). For example, one or more collector sections 126 may be used to collect true nanoscale particles having size A, true nanoscale particles having size B, submicron particles having size C and submicron particles having size D.

The laser supplying the beam 102 is contemplated to be of any type (e.g., wavelength) and output power that is sufficient to ablate material from the target.

The following exemplary nanoscale (oxide) powders can be made using this laser ablation technique:

♦ to make CaO, direct the laser at a target formed of calcium carbonate (i.e., limestone) or calcium hydroxide;

♦ to make Al_2O_3, direct the laser at a target formed of

aluminum hydroxide;

♦ to make MgO, direct the laser at a target formed of magnesium carbonate or hydroxide; and

♦ to make TiN, direct the laser at a Ti target in nitrogen.

The use of carbonates and hydroxides as the target (starting) material is preferred over the use of chlorides and sulfides, because they generally will not produce toxic gases. However, the present invention would work effectively with chlorides, sulfides, sulphates and other compounds and metals.

Metal nanoscale powders can also be formed by the disclosed technique. Generally, a target formed of pure metal source (starting) material such as gold, copper, zinc, etc. would be employed. In the case of metals capable of oxidizing (e.g., zinc, iron), a non-oxidizing carrier gas (e.g., nitrogen) is preferred, unless it is desired to form metal oxide nanoscale powders.

The carrier gas may also perform an important cooling function in addition to its function of carrying the ablated materials across the target to the collector system. Cooling the ablated material is sometimes necessary to trap the ablated particles in their desired state, and to prevent agglomeration (e.g., sticking together) of the particles.

Nanoscale powders (oxides) such as CaO and MgO are useful, inter alia as destructive adsorbents for military chemical wastes or as air purifiers. To form CaO or MgO, the target may be any suitable Ca or Mg containing compound, such as carbides, hydroxides, oxides, chlorides, sulphates, and magnesium metal, or salts of calcium or magnesium, including $CaCO_3$, $Ca(OH)_2$, $MgCO_3$ and $Mg(OH)_2$. For example, the laser beam 102 is controlled to ablate the target 106, causing decomposition of the compound, yielding either CaO or MgO, depending on choice of source material for the target 106. For example, where the target 106 is calcium carbonate ($CaCO_3$), the laser energy 102 ablates the target 106 and decomposes and breaks the $CaCO_3$ into CaO

nanoscale particle 108 and CO_2 gas (byproduct). The CO_2 byproduct will exit the system.

Nanoscale metal powders such as copper, gold and zinc are useful for brazing applications. Due to the relatively high ratio of surface area to volume for such nanoscale particles, they exhibit a lower melting temperature than larger particles of the same material.

As a general proposition, the starting material may be any compound (e.g., calcium carbonate) that is capable of being disassociated into the desired nanoscale powder (e.g., CaO), and the carrier gas may also contribute (e.g., oxygen) to the chemical composition of the desired nanoscale powder.

For laser ablation production of all contemplated nanoscale powders, the laser beam 102 will have preselected laser power and pulse repetition.

High power excimer, CO_2, Nd-YAG, or a combination of these lasers or other energy sources can be used to synthesize nanoscale powders. Operating parameters (e.g., laser power, focus, pulse repetition rate) are dictated by factors such as the desired physical characteristics (e.g., surface area, size distribution) of the nanoscale powder sought to be produced, the target material, the choice of carrier gas and its flow rate.

An important feature of the present invention is that it can be carried out in an ambient environment. Due to extreme chemical reactivity of many nanoparticles, most prior efforts at laser ablation has been carried out in a vacuum for atomic cluster synthesis and thin film deposition. However, since CaO and MgO (and many other nanoscale particles) are relatively stable in atmosphere, preparation of nanoscale particles of these materials in an ambient environment is possible. The same is true of many of the other nanoscale powder materials discussed hereinabove.

An example of the technique of the present invention is to produce lime (CaO) from limestone ($CaCO_3$). The laser ablation technique of the present invention produces temperatures

reminiscent of known kiln processes for decomposing limestone into lime.

A number of naturally-occurring minerals such as limestone, magnesia alba, magnesia limestone, mafic minerals, and magnesia can be used for commercial production of nanoscale particles according to the present invention. For example, pure carbonate compounds can be used for making nanoscale particles according to the present invention. Since all decomposition reactions are known to be endothermic, e.g., limestone decomposes at 825°C, laser technology is ideal for this kind of reaction. A difference between the laser ablation technique of the present invention and conventional (e.g., kiln) heating is that the entire reaction/quenching processes are faster, thereby prohibiting the nanoparticles from agglomerating into large crystallites. Nanoscale grains formed by the technique of the present invention can therefore be trapped.

In another example, forming MgO nanoscale powder from elemental magnesium, nitrogen is preferred as the carrier gas. In this case, magnesium nitride will be formed as an intermediate product which will react with the oxygen in the ambient environment (air) to form magnesium oxide (if magnesium nitride is not desired).

Nanoscale materials have highly desirable properties. For example, melting temperatures of CdS and gold nanocrystals drop by 1000°K when crystallite sizes decrease from 50 nm to 10nm. Microhardness of nanoscale copper increases by a factor of 5 as grain size changes from 50 micrometer to 6 nanometer. Catalytic and normal chemical activities of materials can greatly be enhanced when these materials are formed as nanoscale particles. Ionic conductivity can be increased by a order of magnitude over single crystal materials. Optical absorption also changes drastically. Other significant characterizations are contemplated to be within the scope of the present invention.

ARC HEATING

Figure 2A illustrates a system 200 for making nanoscale powder materials (particles) by electric arc heating.

Starting materials 212, including relatively large size source materials (particles), are deposited by any suitable means onto one end (left, as viewed) of a first conveyor 202 which has any suitable number (five shown) of wheels 204 arranged in a linear series, and a conductive (e.g., metallic) belt 206 encircling the series of wheels.

The first conveyor 202, with its metallic belt, acts as one of two electrodes in the system, and opposes another electrode which may be a second conveyor 208 which has a similar system of wheels 210 and a conductive belt 216.

An important feature of this embodiment of the invention is that the top (as viewed) side of the conveyor belt 206 is flat, and generally parallel to the bottom (as viewed) side of the conveyor belt 216. This establishes a gap of known size between the two opposed surfaces of the two belts. An electric power source 230 is connected across the two belts 206 and 216 (such as with suitable brushes, not shown) so that the belts act as two electrodes for a spark gap. The power output by the source 230 may be either alternating current (AC) or direct current (DC), and is sufficient to cause decomposition of the source material particles into nanoscale powders by arcing between the two electrodes (belts). Arcing between the two electrodes (belts) causes localized, intense heating of the source material particles (212), which causes them to decompose into nanoscale powder particles (214). Particular parameters for the power source will be dependent upon the source materials used and the gap between the two electrodes. As a guideline, the power source should be able to output 110 volts at 10-200 Amperes.

The nanoscale powder particles (214) are conveyed to the end of the conveyor 202 (to the right, as viewed), and are simply dropped (downward, as viewed, by action of gravity) into

a suitable container 232.

In this embodiment, the lateral extent (from left-to-right, as viewed) of the two electrodes (belts) may be similar or identical to one another.

In this embodiment of the invention, the source material may be carbonate, hydroxide, chloride or sulfate (the latter two of which are not preferred due to toxicity), or any other suitable source material.

Generally, the source materials and nanoscale powders produced are similar to those discussed hereinabove with respect to the **Figure 1** (laser ablation) embodiment of the invention.

Using this arc heating technique, it is likely that the size of the nanoscale powder particles may tend to agglomerate. To control (e.g., prevent) agglomeration, it is preferred to cool the decomposed source material particles with a suitable coolant such as liquid nitrogen.

Gases, such as organometallic or metalorganic compounds, may also by used for these processes.

ARC HEATING WITH COOLING

Figure 2B shows an embodiment 250 of the invention similar in many respects to the embodiment 200 of **Figure 2A** in that there is an AC or DC electric power source 280 (compare 230), a first conveyor 252 (compare 202) with a conductive belt (256 (compare 206) encircling a series of wheels 254 (compare 204), and a collection bin 282 (compare 232 at the end of the conveyor 252.

In this embodiment, a second conveyor 258 (analogous to 208) has a series of wheels 260 (compare 210) encircles by a conductive (e.g., metallic) belt 266 (compare 266). However, whereas in the previous embodiment the second conveyor (208) had a similar lateral extent as the first conveyor (202), in this embodiment the second conveyor 258 has a shorter lateral extent than the first conveyor 252. The second conveyor 258 is laterally centered above the first conveyor 252.

In this illustration, source materials are delivered as large particles 262, by any suitable means such as a tube 270, to the top side (as viewed) of the second conveyor 258, whereupon they are conveyed (to the left, as shown) to the end of the second conveyor 258 and dropped onto the top (as viewed) side of the first conveyor 252. The particles 262 are conveyed by the first conveyor 252 to immediately underneath the second conveyor 258, whereupon an electric arc caused by the power source 280 causes their decomposition into nanoscale powder particles 264.

The setup in **Figure 2B** may be aligned so as to eliminate the need for a carrier belt for transferring the starting material and nanoscale particles to the collector. Additionally, flat or cylindrical electrodes may be used.

HIGH-TEMPERATURE FLAME SPRAY

Figure 3A illustrates a system 300 for making nanoscale powders by a technique of high-temperature flame spray. A nozzle assembly 302, similar to the nozzle of an oxy-acetylene torch is used in this technique.

The nozzle assembly 302 comprises the following concentric elements:

- an innermost tapered tube 304;
- an intermediate tapered tube 306 surrounding the tube 304;
- a tubular ferrule (nozzle tip) 308, having a tapered bore, surrounding the tube 306; and
- an outer, generally cylindrical housing 310 surrounding the tubes 304, 306 and the ferrule 308.

Starting (source) material 320 is introduced to the bore of the innermost tube 304 and propelled therethrough by a feeding gas (indicated by arrows 312), which also acts as a carrier gas. The coaxial alignment of the elements 304, 306 and 308 ensure that these particles will be ejected from the opening in the ferrule 308, and they should evidently not be larger than

the opening in the end of the tube 304. The feeding gas may be simply be air.

Fuel (indicated by arrows 314) is introduced into the bore of the intermediate tube 306 - namely, between the outer surface of the innermost tube 304 and the inner surface of the intermediate tube 306. The fuel is preferably in gaseous form, selected from the group of materials consisting of acetylene, propane, hydrogen, and the like. Oxygen may also be introduced into the fuel (i.e., fuel mixture), or may be supplied separately as the feeding gas.

Compressed gas (e.g., compressed air) (indicated by arrows 316) is introduced into the bore of the ferrule 308 - namely between the outer surface of the intermediate tube 306 and the inner surface of the ferrule 308.

In use, the fuel is ignited by any suitable means to cause a flame ("F", encircled by dashed lines) to be present at the orifice of the ferrule (nozzle tip). The flame heats the source material 320 (e.g., $CaCO_3$) to cause its decomposition into nanoscale particles 322 (e.g., CaO). The compressed gas 316 cools ("traps") the nanoscale particles 322, preventing agglomeration of the decomposed nanoscale particles (spreading, or "coning" of the particles conveyed by the compressed gas is indicated by the dashed lines 326). The deflector 324 simply "stops" the nanoscale particles and diverts them into a compartment (334) of a collection bin (330).

A two compartment collection bin 330 is disposed below the plume of particles conveyed by the compressed gas. The bin 330 has a compartment 332 disposed proximal (close to) the nozzle 302 for collecting particles that are larger than nanoscale, and a compartment 334 disposed distal (further from) the nozzle 302 to collect the nanoscale particles. The collection bin 330 functions in a manner analogous to the collection system 118 of **Figure 1**.

Gaseous byproducts of the decomposition reaction simply rise away from the bin 330 and, if toxic, can be collected by

suitable means and properly disposed of.

According to an aspect of this embodiment of the invention, the temperature of the flame is controlled to ensure appropriate decomposition of the starting material. For example, to decompose calcium carbonate, the flame temperature should be maintained at least 825°C (degrees Celsius).

As in the previous embodiments, it may be necessary to cool the nanoscale particles that are produced to avoid their agglomeration. To this end, the compressed gas can act as a coolant.

For this embodiment, the starting materials and nanoscale particles produced are generally identical to the embodiment of **Figure 1** (laser ablation).

HIGH-TEMPERATURE PLASMA SPRAY

Figure 3B illustrates a system 350 for making nanoscale powders by a technique of high-temperature plasma spray. The technique of this embodiment is very similar to the technique of **Figure 3A**, except that a fuel (314) is not used and a plasma (P) is substituted for the flame (F) as the heat source for decomposing the source materials into nanoscale particles.

The following elements are carried over from the previous embodiment: nozzle assembly 302; innermost tapered tube 304; intermediate tapered tube 306; tubular ferrule 308; and outer housing 310.

Starting (source) material 320 is introduced to the bore of the innermost tube 304 and propelled therethrough by a feeding (carrier) gas (indicated by arrows 312). The coaxial alignment of the elements 304, 306 and 308 ensure that these particles will be ejected from the opening in the ferrule 308, and they should evidently not be larger than the opening in the end of the tube 304. The feeding gas may be simply be air.

A heat-transfer medium (indicated by arrows 314) is introduced into the bore of the intermediate tube 306 - namely, between the outer surface of the innermost tube 304 and the

inner surface of the intermediate tube 306. The heat-transfer medium is preferably in gaseous form, such as argon (Ar).

Compressed gas (e.g., compressed air) (indicated by arrows 316) is introduced into the bore of the ferrule 308 - namely between the outer surface of the intermediate tube 306 and the inner surface of the ferrule 308.

In use, the starting material is decomposed by a plasma ("P", encircled by dashed lines) created at the orifice of the ferrule. The plasma (e.g., argon plasma) heats the starting material 320 (e.g., $CaCO_3$) to cause its decomposition into nanoscale particles 322 (e.g., CaO). The compressed gas 316 conveys the nanoscale particles 322, and any residual source materials 320 towards a deflector 324 along a generally linear path (spreading, or "coning" of the particles conveyed by the compressed gas is indicated by the dashed lines 326). The deflector 324 simply "stops" the nanoscale particles and diverts them into a compartment (334) of a collection bin (330). The collection system (324, 330, 332 and 334) is essentially identical to that of **Figure 3A**, and gaseous byproducts of the decomposition reaction simply rise away from the bin 330 and, if toxic, can be collected by suitable means and properly disposed of.

According to an aspect of this embodiment of the invention, the temperature of the plasma is controlled to ensure appropriate decomposition of the starting material. For example, to decompose calcium carbonate, the plasma temperature should be maintained at least 825°C (degrees Celsius).

As in the previous embodiments, it may be necessary to cool the nanoscale particles that are produces to avoid their agglomeration. To this end, the compressed gas (e.g., air) can act as a coolant.

For this embodiment, the starting materials and nanoscale particles produced are generally identical to the embodiment of **Figure 1** (laser ablation).

According to this embodiment of the invention, techniques for inducing the plasma include electric arc, laser, microwave, RF, hot filament, as well as other power transmitting sources such as x-rays, neutrons, etc. By way of example, an AC or DC power source 380 is connected between the innermost tube 304 and the intermediate tube 306.

As is evident, certain elements of a given technique may successfully be incorporated into other techniques. Generally, the techniques disclosed hereinabove are useful for making the following nanoscale powders from the following starting materials using the following decomposing techniques to make nanoscale powders for the following exemplary applications (uses):

nanoscale powder	starting material	decomposing technique(s)	exemplary application
CaO	$CaCO_3$, $Ca(OH)_2$	laser, arc, flame, plasma	adsorbent, catalyst
MgO	$MgCO_3$ $Mg(OH)_2$	laser, arc, flame, plasma	adsorbent, catalyst
TiO_2	$Ti(OH)_4$	laser, arc, flame, plasma	adsorbent, catalyst, ceramics, composites, polishing, coating, painting, engineering, components
VO_2	$V(OH)_5$	laser, arc, flame, plasma	adsorbent, catalyst, ceramics, composites, polishing, coating, painting, engineering, components
Al_2O_3	$Al(OH)_3$	laser, arc, flame, plasma	adsorbent, catalyst, ceramics, composites,

			polishing, coating, painting, engineering, components
FeO	$Fe(OH)_3$	laser, arc, flame, plasma	adsorbent, catalyst, ceramics, composites, polishing, coating, painting, engineering, components
Fe_2O_3	$Fe(OH)_2$	laser, arc, flame, plasma	adsorbent, catalyst, ceramics, composites, polishing, coating, painting, engineering, components
Y_2O_3	$Y(OH)_3$	laser, arc, flame, plasma	adsorbent, catalyst, ceramics, composites, polishing, coating, painting, engineering, components
Au	Au	laser, flame plasma	joining, bonding
Cu	Cu	laser, flame, plasma	joining, bonding
Zn	Zn	laser, flame plasma	joining, bonding
SiO_2	silicon halides, silicates	laser, arc, flame, plasma	adsorbent, catalyst, separation, optics

Evidently, a wide variety of materials can be produced by the techniques of the present invention. For each, the energy source parameters (power, temperature, focus), gas flow rate, pressure and distance/time a particle travel are among the parameters that will affect yield. These parameters, however, will need to be optimized empirically.

Techniques for separating particles by size have been disclosed. It is within the scope of this invention that a sieve or the like may be used to separate the various size nanoscale particles.

COMMENTS DISTINGUISHING THE INVENTION FROM THE PRIOR ART

The aforementioned U.S. Patent No. 4,619,691 ("ARAYA") does not define ultra-fine particles. The present invention expressly discloses techniques for synthesizing nanoscale materials. ARAYA directs a laser beam on a surface of a material, generating a plume. The plume is defined as partly ionized metal vapor of high density. It is pointed out in ARAYA that the plume phenomenon is most remarkable so that an arc energy, an electric discharge energy and an electron beam energy could assist in the process. This is somewhat indirect. The present invention does not require or create a plume, and the starting material is decomposed in a direct manner. For example, according to the present invention, calcium and magnesium carbonates are decomposed into their corresponding oxides, and hydroxides are decomposed into

oxides. These inventive processes do not involve a so-called "plume", and do not require any ionized metal vapor at all. ARAYA apparently uses metals as the starting material, and an Nd-YAG laser - a combination which provides a suitable condition for metal ion formation. A limitation inherent in ARAYA's process is that if materials other than metals (such as oxides, carbonates, sulfates, phosphates, sulfides, etc.) were to be used as the starting material, no plume of ionized metal vapor would be created. A key difference between ARAYA and the technique of the present invention is that the process of the present invention provides endothermic reactions which are initiated and sustained by laser energy. Other differences of note between the present invention and ARAYA include:

(1) ARAYA uses (requires) a chamber. The present invention does not require a chamber.

(2) ARAYA requires reactive gases including methane, Freon, propane, nitrogen or oxygen to create carbide, nitride or oxide. The present invention does not require these gases, the source of these materials being in the solid starting materials themselves. Moreover, ARAYA's use of reactive gases that are generally toxic, requires the enclosed chamber. The present invention is not so restricted.

(3) The present invention features cooling the nanoscale powder to prevent it from agglomerating. ARAYA is silent as to this feature.

(4) ARAYA requires vacuum pumping and pressure regulating

systems, and optical windows to feed the laser beam into the reaction chamber. These mechanisms are not required by the present invention.

The aforementioned U.S. Patent No. 4,289,952 ("HAGGERTY") is directed to producing metal or ceramic powder having a narrow size distribution. The grain sizes contemplated by HAGGERTY are larger than 10 μm. Generally, HAGGERTY admits that his minimum particle size (e.g., 10μm) approximates a minimum wavelength of the beam employed in the process. The smallest wavelength beam available from lasers today is much greater than the size of the nanoscale materials synthesized by the present invention. The present invention does not suffer from the limitations inherent in the HAGGERTY process. HAGGERTY requires a reactor or chamber, instrumentalities that are not required in the process of the present invention. In HAGGERTY, the powder product is deposited on a filter and inert gas passes through the filter under the influence of a vacuum downstream of the filter. These instrumentalities (filter, vacuum system) are not required by the process of the present invention. In HAGGERTY, the laser beam impinges on a copper heat sink, which is water-cooled. This is due to the fact that laser energy (power) is not fully consumed. This (heat-sinking, cooling) is not a consideration in the process of the present invention. The process of the present invention contemplates cooling the resulting powder, not cooling a reactor. Finally, HAGGERTY requires a pressure-regulating system and an optical window, neither of which are

required by the present invention.

The aforementioned U.S. Patent No. 4,556,416 ("KAMIJO") requires a chamber, an evaporation source, a vacuum pumping system, optical windows to feed the laser beam into the reaction chamber. KAMIJO requires a gas of volatile metal compound and/or evaporated metal and a reaction gas. The present invention is not restricted in this manner to volatile or evaporated sources, Rather, the reactions are initiated on surface and bulk solid. KAMIJO requires means for putting said reaction chamber in a discharged state by at least one additional power source consisting of direct discharge current, high frequency discharge and microwave discharge, and requires means for irradiating laser beams through the reaction chamber in a discharged state to heat the mixture. The present invention does not require a reaction chamber, a discharged state, an additional power source, etc.

Using Nanoscale Materials For Joining and Brazing

This aspect of the present invention is directed to, as one of its principal objects, the joining of vanes (blades) to the bowl component of an automatic transmission bowl assembly (impeller or turbine). Various techniques for accomplishing this object are discussed hereinabove.

As is known, an automatic transmission system is a fluid coupling that comprises as its essential components an impeller acting as the driving member (imparting motion to the fluid), a turbine acting as the driven member (being acted upon by the moving fluid), and a stator acting as a reaction element.

Figures 4A and 4B illustrate an automatic transmission impeller assembly 400 of the prior art, which includes an outer bowl component 402, an inner shroud (torus ring) component 404, and a plurality of blade components 406 (406a..406n). The bowl component 402 is bowl-like, as shown. The shroud component 404 is annular, as shown. The blade components 406 are essentially flat, monolithic (i.e., single layer) and arcuate, each blade having an outer (towards the bowl) arcuate edge 408 and an inner (towards the shroud) arcuate edge 410. A peripheral blade-receiving region 403 of the bowl component 402 is toroidal, its contour generally corresponding to the contour of the outer edges 408 of the vanes (blades) 406. The contour of the shroud component 404 corresponds to the contour of the inner edges 410 of the vanes (blades) 406.

As best viewed in **Figure 4B**, the outer edge 408 of a blade (only one of the plurality of vanes (blades) is shown in **Figure 4B** as 406) is provided with three tabs 421, 422 and 423 that fit within corresponding slots 431, 432 and 433, respectively, in the toroidal portion 403 of the bowl component 402. In a similar manner, the blade 406 is provided with two tabs 424 and 425 that fit within corresponding slots 434 and 435, respectively, in the shroud component 404. As is known, after being inserted through the slots 434 and 435, the tabs 424 and 425 are rolled (bent) over on the inner surface of the shroud component to (i) retain the shroud component 404 and to (ii) hold the vanes (blades) in place. Generally, the vanes (blades) are prohibited from disengaging from the bowl component by virtue of being fixed to one another by the shroud component, which restricts their freedom to move in a direction that would cause the outer tabs (421, 422, 423) to disengage from the bowl slots (431, 432, 433). Generally, the bowl slots 431, 432 and 433 extend only partially through the bowl component, from the inner surface thereof. (This is the general case with an impeller. In a turbine component, the slots in the bowl typically extend fully through the bowl.) However, as noted above, the shroud slots 434 and 435 extend completely through the shroud to allow the inner tabs (424 and 425) to pass therethrough and be bent over.

It is generally intended that the vanes 406 fit securely to the inner surface 402a of the bowl component 402, to

prevent leakage of fluid between the vanes and the bowl component, and to maximize impelling of fluid by the vaned (bladed) bowl component. However, as noted hereinabove, this "leakproofness" is difficult to achieve, and various techniques have been proposed addressing this problem. Using mechanical means for securing the vanes to the bowl inevitably results in there being gaps between the vanes and the bowl component, which will result in diminished efficiency, in use. In **Figure 4A**, a stylized gap 412 is shown between the outer edge 408 of the blade and the inner surface 402a of the bowl component 402. **Figures 4A and 4B** are intended to be representative, not comprehensive, of the prior art and are presented to establish a non-limiting context for describing a particular application (usage) of the present invention.

As is shown in **Figures 4A and 4B**, a hub 420 is fitted to the center of the bowl component 402. Typically, the hub 420 is processed in a manner dissimilar from the bowl component. For example, the bowl component may be a casting or stamping, and the hub may be a heat treated (hardened), machined forging. As mentioned hereinabove, any mass heating of the bowl (with the hub in place) is likely to result in the hub losing its temper, and perhaps even distorting its aggregate round shape.

Another problem which has been mentioned hereinabove is that, under pressure (i.e., in operation), the bowl component will tend to balloon (expand), exacerbating any leakage (between the vanes and the bowl) that may already be present,

in addition to imposing a spurious stress on the bowl component. Leakage may also adversely affect the fluid flow characteristics of the fluid coupling (e.g., automatic transmission) under high torque-transmitting conditions.

As a general proposition, the function and purpose of the shroud component (404) is primarily to stabilize the vanes (406), and to direct the fluid flow. As is evident, the shroud component (404) does nothing to attenuate leakage between the vanes and the bowl. Nor is the shroud component (404) capable of significantly attenuating ballooning of the bowl component (402).

According to the invention, components such as vanes (blades) are joined by joining to components such as bowls and shrouds, preferably at relatively low temperatures, without mass heating the components.

JOINING COMPONENTS TO ONE ANOTHER

Figures 5A, 5B and 5C illustrate the technique of the present invention in a stylized (generalized) manner. According to the invention it is desired to join two components together, such as steel components, without mechanical means such as tabs and slots. (Of course, the two components could first be joined, or partially joined, with mechanical means such as tabs and slots, but this is not illustrated in the figure.) To this end, a one of the components 502 is butted up against an other 504 of the components 504 by a suitable positioning (e.g., robotic)

mechanism 506. In this example, an edge 502a of the one component 502 is butted up against a surface 504a of the other component 504, and the edge is expected to substantially conform to the surface. The dashed line 508 extending from the positioning mechanism 506 to the one component 502 indicates end effectors, linkages, control arms, and the like, for grasping the component 502 for positioning the component with the robotic mechanism 506. In order to effect such positioning, for components of complex geometry (such as the bowl 402 of **Figure 4**), it is desirable to have a computer (database) "model" of the stationary component (e.g., 504), which may be held in a jig. In this manner, a plurality of non-stationary components (502) can be brought into a precise position and orientation with respect to locations on the stationary component (504). It is well within the purview of one having ordinary skill in the art to which this invention most nearly pertains to implement such a positioning mechanism (means). As will be evident, such a positioning mechanism is suitable for positioning a plurality of vanes in a bowl of an automatic transmission impeller assembly, for holding the vanes (individually, or in groups) in place for joining (e.g., joining) the vanes to the bowl.

As shown in **Figure 5A**, the components 502 and 504 have been brought together into their desired positional relationship with one another, which is preferably contacting one another.

Next, as illustrated in **Figure 5B**, an elongated strip of joining material 510 is applied along the entire length of the junction of (at the seam between) the two components 502 and 504. As shown, the joining material 510 may be applied on both sides of the junction (i.e., both sides of the component 502), but the joining material need only be applied to at least one side of the junction (as shown in **Figure 5C**). As discussed in greater detail hereinbelow, the joining material 210 may or may not be a "self-sustaining" material, and may or may not contain nanoscale-size particles (powders). The joining material may be in the form of a paste, a powder, a tape, an aerosol "painted" onto the components being joined, a pre-peg, etc. For example, a slurry (i.e., a mixture of elements) of a joining material can be formed on a transfer tape having a sacrificial backing, and applied by the medium of the tape to a joint to be brazed. Alternatively, a slurry of joining material could be printed (using screen printing techniques) onto specific areas of components (workpieces) to be joined by joining.

Next, as illustrated in **Figure 5C**, an energy source provides an energy beam 522 directed at the joining material 510 to react or to ignite the joining material and cause the two components 502 and 504 to be joined (e.g., brazed) at the junction thereof.

The energy beam 522 is generated by any suitable means (520) such as a laser (for example an Nd:YAG or a CO_2 laser), flame, arc, plasma, spark, or the like, and is preferably

controllable (such as with positionable mirrors, nozzles and the like - not shown) to be "walked" along the joining material 510. (In the case of a flame, arc or plasma, the beam 522 would not be a beam, per se, as it would be in the case of a laser energy source. However, the showing of a beam 522 is illustrative of the "outputs" of these alternative energy sources.) One having ordinary skill in the art to which this invention most nearly pertains will readily understand how to implement such motion control (e.g., directing the beam at a point, walking the beam along a joint, etc.) over a suitable energy beam.

The invention takes particular advantage of low-melting temperature joining materials such as have been disclosed in the aforementioned, commonly-owned, copending U.S. Patent Application No. 08/296,550. These materials include nanoscale (defined herein as ≤100 nanometers) size particles (powders) of gold, cadmium, copper, zinc, and the like. As noted therein, such nanoscale powders, having a relatively large surface area as compared with their volume, will exhibit a greatly reduced melting temperature (i.e., as compared with non-nanoscale particles). This makes their use ideal for applications where "normal" joining temperatures (of approximately 1000°C) would cause undesirable distortion, annealing, or the like of one or both of the components being joined together. Nanoscale powder joining materials can be melted (recrystallized) to bond (join) the two components together at significantly lower temperatures (i.e., than the

same materials in a bulkier, non-nanoscale phase) - for example, lower than 400°C. Such an "order of magnitude" improvement over traditional (high temperature) joining techniques affords numerous advantages expanding the utility of joining technology to applications heretofore deemed inappropriate for joining.

Among the exemplary advantages of using nanoscale materials (i.e., versus non-nanoscale materials) for joining (e.g., joining) components together is that the smaller size nanoscale materials allow the components being joined to be positioned closer together (with a smaller gap therebetween), which can result in more uniform joining of the components.

As mentioned above, a laser (520) can advantageously be employed to melt (react) the joining material, and can also be used to initiate a self-sustaining joining material. The benefits of using a laser (e.g., versus an electric arc, a flame, etc.) include:

(a) penetration depth (i.e., into the components being joined) can readily be controlled simply by controlling the laser output power;

(i) in the case of using the laser solely to initiate a self-sustaining joining material, penetration depth is, essentially, a non-issue;

(b) local heating, generally achieved by controlling the spot size (e.g., focussing) of the beam, ensures little heat transfer to the components being joined, and maximizes the energy on the joining material. The benefits of this feature

include:

(1) greatly reduced thermal distortion of the component(s) being joined ("workpiece");

(2) joining (e.g., joining) can be performed in close proximity to heat-sensitive components; and

(3) metallurgical damage of the workpiece, such as grain growth and annealing, is readily avoided.

(c) laser joining, such as disclosed herein, is well suited to automation.

There are several benefits of using nanocrystalline materials as, or as a component of, the joining material (e.g., paste, powder, etc.). Since surface atoms have lower coordination numbers than their bulk peers (larger particles of the same material) do, the mean square displacements of the atoms in crystallite increases significantly as the crystallite decreases and the number of surface atoms increases. Nanocrystalline materials (e.g., particles) have a very high surface area (for a given volume), and a significant portion of the atoms in a given nanocrystalline particle are on the surface of the particle. In fact, one may consider nanocrystalline materials as a transition structure between a bulk solid lattice and a single molecular structure. Consequently, many of the properties of bulk materials are significantly affected. For example, the melting points of nanocrystalline materials will tend to exhibit melting points that are much lower than those of a comparable bulk solid.

For example, the melting points of many nanocrystalline metal phases are lower than 400°C (whereas their bulk counterparts exhibit melting temperatures that are well in excess of 1000°C).

Aluminum and magnesium are preferred materials for incorporating into the joining material (powder) paste, especially in their nanocrystalline form. (However, it should be understood that nanoscale aluminum is more readily obtained than nanoscale magnesium.) In the first instance, aluminum and magnesium are both extremely exothermic. Once they are ignited, the reaction (e.g., their burning) will sustain itself so long as the elemental metal remains. In fact, the oxidation reaction of aluminum gives off so much heat that it has been used to melt steel, for example, in the railway industry. (The heat of formation of Al_2O_3, from oxidation of aluminum, is -399.1 Kcal/mol. The enthalpy of fusion incident to iron and aluminum are only 3.6 and 2.6 Kcal/mol, respectively. This means that one mole of Al_2O_3 formed will provide sufficient heat to melt 112 moles of iron.)

According to the invention, a joining material containing aluminum and/or magnesium nanoscale powders is employed to effect not only low-temperature joining, but also to effect a self-sustaining reaction requiring only that a spot of the joining material be lit (ignited) to react the entire amount of joining material. The heat released by the exothermy of the reaction will sustain the reaction of the entire amount of joining material incorporating these exothermic materials.

An exemplary joining material, having a significant content of both aluminum and magnesium nanoscale particles, is described hereinbelow. It is within the scope of this invention that only one of the nanoscale components (aluminum and magnesium) is utilized in the self-sustaining joining material. Of these two components, if only one were available, there would be a slight preference towards aluminum.

It is within the scope of this invention that the joining material and the beam are applied simultaneously to the junction of the two components being joined together (i.e., rather than first applying an elongated strip of joining material along the length of the to-be-formed joint, then reacting the elongated strip of joining material, as implied by **Figures 5B and 5C**). One having ordinary skill in the art to which this invention most nearly pertains will recognize, in light of the teachings contained herein, that powders (e.g., powders containing nanoscale particle components) can be delivered by means of a suitable pressurized nozzle, which is preferably mechanized. Evidently, when delivering the powder simultaneously (contemporaneously) with applying the energy (from the source 520), the powder and the beam (522) from the source (520) should both be directed at the same spot on the to-be-formed joint to ensure melting (reacting) of the joining material at that location.

The present invention advantageously employs a laser to react and/or ignite a joining material which preferably contains nanoscale, exothermic materials. A beam from the

laser can be walked along a previously-applied amount of joining material, to react (e.g., melt) the joining material, or can be used to ignite a localized portion of a self-sustaining, exothermic joining material.

In a preferred embodiment of the invention, particularly applicable to joining vanes to the bowl of an automatic transmission impeller assembly, an Nd:YAG laser having a 200 W (Watt) output, emitting pulses of 0.5 ms (millisecond) duration at a frequency of 260 Hz (Hertz), with a beam diameter of approximately 1.5 mm (millimeters) is scanned over an amount of joining material (e.g., in the form of an elongated strip having a length of approximately two inches) in less than one second.

In an alternate embodiment of the invention, an Nd:YAG laser having a 500 W (Watt) output, emitting pulses of 1.0 ms (millisecond) duration at a frequency of 260 Hz (Hertz), with a beam diameter of approximately 1.5 mm (millimeters) is scanned over an amount of joining material (e.g., in the form of an elongated strip having a length of approximately two inches) in less than one second.

Example 1:

In an embodiment of the invention, particularly applicable to joining vanes to the bowl of an automatic transmission impeller assembly, but not limited thereto, a "self-sustaining" (exothermic) joining material having the following material composition is employed:

material	% (by weight)	particle size
Cerium	2%	<1μm
Boron	3%	<1μm
Chromium	5%	<1μm
Nickel	12%	<1μm
Magnesium	18%	<1μm
Aluminum	15%	nanoscale
Tin	2%	1-3μm
Zinc	5%	1-3μm
Copper	20%	1-3μm
Silver	18%	1-3μm

The relative amounts of these materials (elements, ingredients) can be incremented (or decremented), as desired for a particular application and, if nanoscale magnesium is available, it would be preferred in a mixture of a self-sustaining joining material.

Generally, elements such as chromium, nickel and boron contribute a fluxing function to the joining material; elements such as aluminum or magnesium imbue the joining material with its self-sustaining characteristic; and elements such as silver and copper contribute to the ductility, bond strength and fatigue strength of the resulting joint.

Generally, the particular elements will be selected according to the desired bond strength of the resulting joint, the materials of the components being joined, and other

application-specific parameters.

Example 2:

Another mixture of elements suitable for use as a joining material, according to the present invention, comprises:

boron (<1μm); nickel (<1μm); nanoscale aluminum; copper (1-3μm) silver (1-3μm); and iron (preferably nanoscale).

Example 3:

Another mixture of elements suitable for use as a joining material, according to the present invention, comprises:

chromium (preferably nanoscale), aluminum (preferably nanoscale), and iron (preferably nanoscale).

Example 4:

Another mixture of elements suitable for use as a joining material, according to the present invention, comprises:

boron, chromium (preferably nanoscale), zinc (preferably nanoscale) and silver (preferably nanoscale)

As applied to joining vanes to the bowl of an automatic transmission impeller, as discussed below (with respect to **Figure 6**), using such a joining material (e.g., the joining material of Example 1), in conjunction with the techniques of

the present invention (e.g., initiating the self-sustaining joining material with a laser), resulted in a bond (braze) strength greater than 130,000 psi (pounds per square inch), and in overall (mass) heating of the bowl to only 35°C (degrees Celsius), with localized heating of only 65°C.

It should be understood that, although the invention is principally described in the context of joining a plurality of vanes to a bowl of an automatic transmission impeller, the techniques described herein are applicable to virtually any other milieu wherein it is desired to effect the joining of two components in a controlled manner, especially when mass heating, or overheating an adjacent area of the workpiece, are of concern and are desired to be minimized or avoided.

Joining VANES IN AN IMPELLER

Figure 6 illustrates components of an automatic transmission impeller assembly 600, assembled according to the techniques of the present invention, which includes an outer bowl component 602, an inner shroud component 604, and a plurality of blade components 606 (606a..606n). The bowl component 602 is bowl-like (semitoroidal), as shown. The shroud component 604 is annular, as shown. The blade components 606 are essentially flat and arcuate, each blade having an outer (towards the bowl) arcuate edge 608 and an inner (towards the shroud) arcuate edge 610. A peripheral blade-receiving region 603 of the bowl component 602 is arcuate, its contour generally corresponding to the contour of

the outer edges 608 of the vanes 606. The contour of the shroud component 604 corresponds to the contour of the inner edges 610 of the vanes 606. As is known, it is desired to mount the vanes 606 generally radially, with respect to an axis of rotation of the bowl. As is known, the bowl may be provided with a central hub 620, which is heat-treated, hardened steel.

In contrast to the impeller assembly 400 of **Figure 4**, in the impeller assembly 600 of **Figure 6** the outer 608 and inner 610 edges of the vanes 606 may or may not be provided with tabs (421..425) that fit within corresponding slots (431..435) formed in the bowl (402) and shroud (404) components, respectively. Rather, the vanes 606 are formed to fit precisely between the inner (towards the shroud) surface 602a of the bowl component 602 and the outer (towards the bowl) surface 604a of the shroud component, and are joined by a joining materials 612 and 614 (compare 510) to the bowl 602 and shroud 604 components, respectively, so that the vanes are secured within the bowl in a manner that avoids (or, at least minimizes) leakage between the vanes and the bowl and provides stiffening for the bowl, and that lends itself well to automated assembly procedures. Vis-a-vis avoiding (minimizing) leakage, it is preferred that the entire length of at least one side of each vane is brazed to the inner surface of the bowl. In this manner, there will be no gaps (compare 412) impeding the efficient impelling of transmission fluid, and there will be a corresponding increase in impeller

efficiency which will translate to an increase in overall fuel efficiency for an automobile equipped with such a brazed-vane impeller. Generally, the present invention requires joining the vanes at least to the bowl, and optionally to the shroud. In the case of joining the vanes to the shroud, it is contemplated that the vanes would have tabs extending through slots in the shroud and, after being bent over, are brazed to the shroud. It is within the scope of this invention that the vanes are brazed solely to the bowl, and are affixed to the shroud using conventional tabs and slots. It is also within the scope of this invention, as will become evident from description presented hereinbelow, that it is not necessary to have a shroud securing the inner edges of the vanes at all.

Vis-a-vis joining the banes to the shroud, without tabs and slots, by joining, assembling the vanes first to the bowl makes the joint between the vanes and the shroud somewhat inaccessible. In order to effect joining with a laser (and, preferably, using self-sustaining joining material), the beam (522) from the laser (520) is directed through a fiber optic cable having sufficient capacity to sustain the energies involved. Manipulation of the beam at these relatively inaccessible joints is readily accomplished with the use of a positioning mechanism (e.g., an industrial robot with appropriate end effectors).

Figure 6 is intended to be representative, not comprehensive, of the many and varied application of the techniques of the present invention. For example, it is well

within the scope of this invention that a plurality of vanes are brazed to the bowl of a torque converter turbine, in a manner similar to joining a plurality of vanes to the bowl of a torque converter impeller. In aggregate, the impeller bowl and the turbine bowl components are termed "bowl components" of an automatic transmission.

Among the numerous advantages of using the techniques of the present invention to affix a plurality of vanes to the bowl of an automatic transmission impeller assembly are:

(a) the brazed joint is sealed (leakproof, or leakage minimized) along its entire length, thereby enhancing the fluid dynamic efficiency of the impeller assembly;

(b) there is no significant mass heating of the bowl, thereby circumventing distortion and/or annealing of the bowl;

(c) the number, angle and shape of vanes affixed to the bowl are readily changed, without modifying the bowl (e.g., the slot arrangement in the bowl); and

(d) the process is highly automatable (e.g., the vanes are readily positioned in the bowl by robotic equipment, the joining material is deliverable in various forms, and the energy are also readily delivered by automated equipment).

Another advantage of the present invention, vis-a-vis the prior art joining techniques discussed hereinabove, is that it is not necessary first to create a subassembly of vanes and shroud, then insert the subassembly into the bowl for joining. (However, it is within the scope of this invention that the vanes are first brazed to the shroud, then the subassembly of

vanes/shroud is placed into a bowl, and the vanes are brazed to the bowl.) First of all, those techniques are more aptly suited to furnace (mass) heating of the bowl, which suffers from the problems associated with mass heating described above. Moreover, using those techniques requires the use of a jig to hold the vanes in place while the shroud is assembled to the vanes to create the subassembly.

According to an aspect of the present invention, a plurality of vanes are assembled (brazed) to a bowl component of an automatic transmission, one-by-one (or in groups, such as in diametrically opposed pairs of vanes), prior to joining the shroud component to the assembly (if at all). Preferably, the bowl component is held stationary, and the vanes are positioned in the bowl component by a suitable positioning mechanism (compare 206). Once in position, each vane is brazed, individually, to the bowl component, preferably by applying an elongated strip of the joining material along the entire length of the joint, then igniting the self-sustaining joining material with a directed beam from a laser.

Alternatively, it is possible to place all of the vanes into the bowl component, then braze them (e.g., one-by-one). This is facilitated, especially in the case of tabless vanes, by using a magnet (e.g., disposed under the bowl component) to temporarily hold the vanes in place, for subsequent joining.

As mentioned above, a laser beam is suitably directed at the joining material (preferably a joining material containing nanoscale aluminum and/or magnesium elements) to effect

joining of the two components. Since the cross-section and focus of such a beam can be controlled, this allows for localized heating during the joining process. For example, a laser beam having a cross section of 1mm (one millimeter) is suitable for joining vanes to bowl components, as described above. Generally lasers operating in the visible and infrared wavelengths are preferred for performing this heating (and igniting) function, ultraviolet lasers not being as efficient for heating and possibly causing undesired deposition sputtering.

As mentioned with regard to **Figures 5A-5C**, it is possible to first apply an elongated strip of joining material along the entire length of a joint between two components desired to be joined, and then "walk" the laser beam along the length of the elongated strip of joining material or, alternatively, to initiate a self-sustaining (exothermic) reaction by directing the laser beam at a single spot (localized area) on the elongated strip of joining material (e.g., such as at the end of the elongated strip of joining material so the reaction propagates unidirectionally along the length of the elongated strip of joining material, or at an intermediate portion of the elongated strip of joining material so that the reaction propagates bidirectionally along the length of the elongated strip of joining material). It was also discussed that the joining material (e.g., paste, powder) can be delivered to the joint simultaneously with delivery of the laser beam.

Figure 7 illustrates a nozzle 700 suitable for simultaneously (and, essentially coaxially) applying a joining material to a junction between two components while directing energy from a source (e.g., a laser) at the junction, to join the two components such as by joining. The nozzle 700 has an annular, ring-like body portion 702 with an opening 704 extending therethrough (from "top" to "bottom"). A runner, or manifold 706 is disposed circumferentially throughout the body portion 702. A plurality (one or more) of output orifices 708 extend from the manifold 706 to the opening 704 at an angle, so as to be directed at (aligned with) a point "P" that is co-axial with, but offset below the nozzle. A single input orifice 710 communicates with the manifold 706 from exterior the nozzle body 702.

In use, material (such as joining material having nanoscale components) is supplied to the input orifice 710 of the nozzle from a source (not shown), and is directed at the point "P" as indicated by the dashed line(s) 712. Simultaneously, energy from a source, such as in the form of a laser beam, is directed through the nozzle at the point "P", as indicated by the line 714. In this manner, joining material (712) can be applied to a specific point (or small area) between two components, simultaneously with being heated to form a joint between the two components. When two or more output orifices 708 are provided, they should be aligned so that joining material exiting from each output orifice is coincident at the point "P". To form an elongated joint

between the two components, the entire nozzle would be moved along the junction of the two components.

Figure 7A illustrates an alternative embodiment for simultaneously delivering joining material and reacting energy to a joint between two to-be-joined components. The joining material is delivered by a nozzle 752, and is directed (as indicated by the arrow 762) at a point "P". Energy, such as from a laser, is also directed at the point "P", as indicated by the arrow 764.

Generally, as noted above, the invention contemplates laser joining of two or more articles (components, workpieces), using a joining material which may be the same as or different from the articles being joined. In all likelihood, the components being joined will not have the same material composition as the joining material. Although energy sources other than a laser are discussed, the use of a laser is generally preferred due to the ability to control the beam and consequent ability to localize heating of the junction between the two articles.

Depending upon the application for the joining techniques discussed above, and taking into account concerns that may exist over annealing and/or softening of the articles being joined, the laser operating parameters (e.g., wavelength, focus) can readily be adjusted to suit the application, and the characteristics (e.g., melting point and composition) of the joining material can readily be selected. The joining material may include self-synthetic/reactive materials. Among

the advantages of the invention are the ability to exploit material characteristics of the articles being joined to limit adverse heat effects on the material of the articles, while ensuring high tensile strength of the joint being formed, limiting creep, and enhancing corrosion and fatigue resistance.

The joining material (e.g., 510, 612, 614) may be in the form of a gas, a solid, a liquid, or a solid/liquid mix. For joining steel articles, preferred joining materials include aluminum, magnesium, chromium, nitrogen, boron powders, iron, zinc, silicon, copper, silver, carbon, and combinations thereof.

It has been discussed, hereinabove, how the joining material and a laser may be simultaneously introduced to the junction of two components to be joined, and how the combination of joining material and laser may traverse the length of the junction. It is within the contemplated scope of this invention that the combination of joining material and laser not traverse the length of the junction. It may be possible to initiate the joining at one end (of the junction), and then have a continuous reaction extending to the other end of the junction (e.g., by traversing the length of the junction with joining material only, sans continued application of the laser after initiating the reaction).

Where the area to be joined is small (e.g., sub-micron), it may be necessary to use tightly-focused ultraviolet lasers and nanoscale joining materials.

HOLLOW VANES (BLADES)

As mentioned hereinabove, one purpose of the shroud is to stabilize and/or rigidize the vanes by securing their inner edges (typically via tabs and slots). **Figures 8A and 8B** illustrate a technique for fabricating vanes that are more stable and/or rigid than the one-layer vanes of the prior art.

Figure 8A shows a flat piece (single layer) of sheet metal which has been cut (stamped) into the shape of two arcuate sides 802 and 804 of an impeller blade. The side 802 has the arcuate shape of the impeller blade 606 of **Figure 6**, and the shape of the side 804 is similar to the shape of the side 802. The side 804 is somewhat oversize, being provided with marginal regions 805, 806 and 807, outside of dashed lines 815, 816 and 817 that are intended to be bent over (as indicated by the arrows 815, 816 and 817, respectively), towards the side 802, when the side 804 is folded towards the side 802 (as indicated by the arrow 830) in order to impart a hollow, tubular structure to the finished impeller blade. The blade, so folded, and with its marginal regions bent, is shown in **Figure 8B**. A marginal region 808 is disposed between the dashed lines 818 and 819, which are the ends of the respective sides 802 and 804. In **Figure 8B**, the marginal region 805 is illustrated only partially bent over to meet the edge of the side 802.

Upon folding the side 804 towards the side 802 (arrow 830), and bending the marginal regions to meet the respective edges of the side 802, the edges of the marginal regions and

the respective edges of the side 802 are joined together in any suitable manner, such as by joining, soldering or welding. Preferably, the joining technique of the present invention is employed to effect this edge-joining.

Figure 8C and 8D illustrate an alternative technique for forming hollow vanes. In **Figure 8C**, a tubular stock 850, which may be in the form of a hollow ring having an outer periphery 852 and an inner periphery 854, is cut off at positions 856 and 858. The stock between these two positions 856 and 858 is then partially flattened, as shown in **Figure 8D**, to form a hollow arcuate element suitable for use as a vane in an automatic transmission bowl assembly. The side edges 856 and 858 may be pinched off and joined, to add to the rigidity of the hollow vane.

Figures 8A-8D are merely exemplary of techniques for forming hollow vanes. Generally, as will be evident, the increased rigidity accruing to a hollow (versus monolithic) vane can advantageously be employed to form shroudless bowl assemblies, as described hereinbelow. Generally, a hollow vane will exhibit greater inherent rigidity, as well as improved fluid dynamics, than the single layer vanes of the prior art, and it is contemplated by the present invention that vanes formed in this manner can be mounted to the bowl of an automatic transmission impeller without requiring a shroud to stabilize the vanes. Such vanes are preferably brazed to the bowl using the low-temperature, self-sustaining joining material techniques disclosed herein.

There have been described a number of different techniques for forming hollow vanes. It is within the scope of this invention that other techniques for forming hollow vanes be employed.

STATOR COMPONENT

The discussion presented hereinabove has emphasized the impeller and turbine assemblies of an automatic transmission. As is known, an automatic transmission typically includes three major components in its fluid coupling: (a) the impeller assembly, (b) a turbine assembly, and (c) a stator assembly. **Figure 9** shows a typical arrangement 900 of these three components, wherein the turbine assembly 904 is similar to (for illustrative simplicity) and disposed facing the impeller assembly 902, and the stator assembly 906 is disposed between the impeller assembly 902 and the turbine assembly 904. Each of these three assemblies are provided with vanes 912, 914 and 916, respectively. The inner edges of the vanes 912 (compare 406) are retained by a shroud 922 (compare 404), and the inner edges of the vanes 914 (compare 406) are retained by a shroud 924 (compare 404). An outer ring 626 is disposed on the periphery of the stator 906. The turbine assembly 904 is of slightly smaller outside diameter than the outside diameter as the impeller assembly 902, so that the impeller bowl overlaps the turbine bowl. As is evident, the stator assembly 906 is smaller than either of the impeller assembly 902 or the turbine assembly 902, its outer diameter being approximately

equal to the inner diameter of the shrouds 922 and 924. Typically, the vanes 912 and 914 are notched (as shown) to accommodate the outer ring of the stator 906. Moreover, it is evident that the shrouds 922 and 924, although spaced from one another, form an annular ring.

In the illustration of **Figure 9**, "inner" components (such as hubs, shafts, and the like, of the automatic transmission are omitted, for illustrative clarity. Moreover, as will be evident, the invention is principally directed to the structure of the outside (outer periphery) of the stator, rather than to its inner (e.g., towards the axis of rotation) "workings". Hence, the inner workings of the stator are stylized, for illustrative clarity.

Generally, the stator 906 performs its principal function at low operating (rotating) speeds, preventing hydraulic fluid from being flung back at the impeller 902 by the turbine 904. The vanes 916 of the stator 906 are shaped so that they redirect the hydraulic fluid being flung back by the turbine at the impeller in the same direction that the impeller is moving and already throwing fluid.

As is evident from the cross-section of **Figure 9**, the shrouds 922 and 924 effectively block transmission fluid from flowing between the impeller and the turbine at a radial "dead" zone (Z1) occupied by the shrouds, the transmission fluid being caused to flow from the impeller to the turbine in a radial zone (Z2) outside of the radial zone (Z1) occupied by the shrouds, and transmission fluid which is flung back from

the turbine at the impeller being directed (i.e., redirected) by the stator in a central region (Z3) interior of the radial zone (Z1) occupied by the shrouds. Generally, fluid does not flow in a central (axial) zone (Z4) is occupied by hubs, shafts, one-way clutches, thrust bearings and the like, all of which are omitted from the figure (for illustrative clarity). The overall flow of hydraulic fluid, from the impeller, around the outer zone (Z2), across the turbine vanes (614), back through the stator (606) in an inner zone (Z3) is generally indicated by the arrow 930. As is evident, the dead zone (Z1) is of significant extent which, intuitively, is of little or no benefit to the desired goal of imparting motion (via the hydraulic medium) from the impeller to the turbine.

According to a feature of the invention, vanes (912, 914) are secured to the bowl components (902, 904) of an automatic transmission without shrouds (922, 924), preferably by the technique of joining as discussed hereinabove. The dead zone (Z1) is more effectively controlled, and the construction of the bowl components (902, 904) is simplified (e.g., by being shroudless), by extending the stator component (906) into the dead zone. This permits "tailoring" the dead zone to achieve configurable performance of the automatic transmission without modifying the bowl component assemblies.

In one embodiment of the invention, the stator component has an annular ring disposed about its periphery, the annular ring being of similar size and radius to the shroud components that it "replaces".

In another embodiment of the invention, the stator component is provided with a disc like ring, disposed about its periphery and aligned radially, extending into the dead zone otherwise occupied by the shroud components. This permits the vanes (912, 914) of the bowl component assemblies to be larger, extending nearly to the marginal disc of the stator. In either embodiment, by eliminating the shrouds (922, 924) retaining the inner edges of vanes (912, 914) on the impeller (902) and turbine (904) bowl components of an automatic transmission, the flow-directing (flow-blocking) function of the shrouds (e.g., of the annular ring formed by the opposing shrouds on the impeller and turbine assemblies) is "subsumed" by the stator assembly. This provides the flexibility for designers skilled in fluid dynamics to optimize turbine, impeller and stator interface designs.

Figure 9A shows an embodiment 940 of relevant components of an automatic transmission, according to an embodiment of the present invention, a notable feature of which is that there is no shroud components (compare 922, 924), and the stator is caused to extend "disc-like" into a zone (Z1) which otherwise would have been occupied by the shroud components. An impeller bowl (omitted from this figure, for illustrative clarity) is provided with a plurality of vanes 942, each of which is generally arcuate in a manner similar to the vanes (612, 406, 606) described hereinabove, and each of which may be fabricated as hollow vanes, as described hereinabove. Joining the vanes 942 to the impeller bowl, using low

temperatures as described hereinabove, is preferred. A turbine bowl (omitted from this figure, for illustrative clarity) is provided with a plurality of vanes 944, each of which is generally arcuate in a manner similar to the vanes (612, 406, 606) described hereinabove, and each of which may be fabricated as hollow vanes, as described hereinabove. Joining the vanes 944 to the turbine bowl, using low temperatures as described hereinabove, is preferred.

A stator 946 is provided with a plurality of vanes 948, preferably disposed on the stator in the inner zone (Z3), as in the prior art (see, e.g., **Figure 6**). In this embodiment, the stator extends into the intermediate "dead" zone (Z2) which otherwise would have been occupied by the shrouds (922, 924). The peripheral edge of the stator is provided with an annular ring (torus) 950, which may be formed as a part of the casting of the stator, or which may be added as a separate element to the stator. The ring 950 is circular, or nearly-circular (i.e., elliptical), and is disposed so as to be in the same location as the shrouds (922, 924) which it "replaces" (i.e., functionally, with regard to controlling fluid flow), and has a cross-sectional diameter which is no greater than, and preferably only slightly smaller than, a circular space defined by the inner edges of the vanes 942 and 944 (so that the ring does not contact the vanes). The vanes 948 perform the flow re-directing (reversal) function of the vanes 916 of the prior art, and the peripheral extension of the stator (including the ring 950) performs the flow-

directing function of the shrouds (922, 924) of the prior art.

Figure 9B shows an alternate embodiment 970 of relevant components of an automatic transmission, according to an embodiment of the present invention, a notable feature of which is that there is no shroud components (compare 922, 924), and the stator is caused to extend into a zone (Z1) which otherwise would have been occupied by the shroud components. An impeller bowl (omitted from this figure, for illustrative clarity) is provided with a plurality of vanes 972, each of which is generally semicircular (rather than arcuate), and each of which may be fabricated as hollow vanes, as described hereinabove. (The vanes 972 and 974 have a generally straight inner edge, versus the arcuate inner edge of the vanes 912 and 914 of the prior art.) Joining the vanes 972 to the impeller bowl, using low temperatures as described hereinabove, is preferred. A turbine bowl (omitted from this figure, for illustrative clarity) is provided with a plurality of vanes 974, each of which is generally semicircular (rather than arcuate) and each of which may be fabricated as hollow vanes, as described hereinabove. Joining the vanes 974 to the turbine bowl, using low temperatures as described hereinabove, is preferred.

A stator 976 is provided with a plurality of vanes 978, preferably disposed on the stator in the inner zone (Z3), as in the prior art (see, e.g., **Figure 9**). In this embodiment, the stator extends into the intermediate "dead" zone (Z2) which otherwise would have been occupied by the shrouds (922,

924). The peripheral edge of the stator is provided with a disc-like (flat ring-like) extension 980, which may be formed as a part of the casting of the stator, or which may be added as a separate element to the stator. The peripheral disc extension 980 is disposed so as to be in the same location as the shrouds (922, 924) which it "replaces" (i.e., functionally, with regard to controlling fluid flow), and has a thickness corresponding to (no greater than, preferably only slightly smaller than) to a gap between the straight inner edges of the vanes 972 and 974 (so that the disc extension does not contact the vanes). The vanes 978 perform the flow re-directing (reversal) function of the vanes 916 of the prior art, and the peripheral extension of the stator (including the disc extension 980) performs the flow-directing function of the shrouds (922, 924) of the prior art. In this embodiment, the radial extent of the disc extension 980 is readily altered to permit more flow from the impeller to the turbine (i.e., by shortening the disc extension, thereby increasing the extent of the zone Z2) or to permit less flow from the impeller to the turbine (i.e., by lengthening the disc extension, thereby decreasing the extent of the zone Z2). In this manner, the "behavior" (energy transfer characteristics) of hydrodynamic coupling between the impeller and the turbine is readily controlled, and altered for different circumstances (e.g., street driving, racing, etc.). For example, for vehicles which are driven primarily at high speeds, and which are not required to undergo repeated stopping and starting, it may be

preferred to shorten the disc extension to permit maximum flow of hydraulic fluid from the impeller to the turbine at medium-to-high engine RPMs.

In the shroudless embodiments, using an extended stator, described hereinabove, it is desired that the vanes are sufficiently rigid to not require a shroud to stabilize their inner edges. Although the hollow vanes disclosed herein satisfy this requirement, it is within the scope of this invention that any stiff vane, including monolithic (single layer, not hollow) vanes, would be advantageously employed with the stator of the present invention. A notable feature of the stator of the present invention, contrasting with the prior art stator described hereinabove (see, e.g., **Figure 9**) is that the stator (which is disposed between the impeller bowl and the turbine bowl and between the vanes of these respective bowls) extends radially to at least a radial midpoint of the vanes. The radial extent of the prior art stator (906) is limited by the shrouds (922, 924) which are disposed at the radial midpoints of the vanes (912, 914).

HEMMING AND LAMINATING

In **Figures 5A, 5B and 5C**, discussed hereinabove, it was demonstrated that two metal components can be joined together, by joining an edge of a one of the two components to a surface of the other of the two components. This technique is particularly pertinent to the joining of vanes to the bowl of an impeller assembly. In **Figures 10A and 10B**, the

description of which follows immediately hereinbelow, the applicability of the present invention to the joining of two components in other configurations is demonstrated.

Figure 7A shows a technique 700 for "hemming" two, in this example flat, pieces of metal 1002 and 1004 together. The joining techniques of the present invention are advantageously employed to effect this purpose.

An edge portion 1006 of the one piece of metal 1002 extends (advertently) beyond the corresponding edge 1008 of the other piece of metal 1004. The extending edge portion 1006 of the piece 1002 is bent over (e.g., 180°, or folded nearly back upon itself) to "capture" an edge portion (from the edge 1008 inward) of the piece 1004.

Joining material 1010, preferably a low temperature joining material having a composition according to the present invention, is disposed (by any of the aforementioned means) along a joint formed at the extreme edge 1012 of the piece 1002 and a region 1014 of the piece 1004 immediately underlying the edge 1012.

A laser 1020 directs a beam of energy (as indicated by the arrow emerging from the laser) at the joining material 1010 and either (i) walks along the elongated strip of joining material to effect joining of the two pieces 1002 and 1004, or (ii) initiates a self-sustaining joining material such as has been described hereinabove.

This technique of joining two metal pieces together, such as by hemming and low-temperature joining, permits the two

pieces of metal to be joined without significant mass heating, and the various advantages of the present invention accruing to avoiding significant mass heating will be attained.

Figure 10B shows a technique 1050 for "laminating" two, in this example flat, pieces of metal 1052 and 1054 together. The joining techniques of the present invention are advantageously employed to effect this purpose.

A thin layer 1060 of joining material, preferably a self-sustaining joining material formulated according to the techniques of the present invention disclosed hereinabove, is disposed between opposing surface 1056 and 1058 of the two pieces 1052 and 1054, respectively. This "sandwich" of metal/joining material/metal could be disposed in an oven to effect melting of the joining paste and joining of the two metal pieces. However, such mass heating would result in all of the disadvantages of mass heating described hereinabove.

According to the present invention, the joining material which is sandwiched between to-be-laminated pieces of metal is initiated by a laser 1070 directing a beam (as indicated by the arrow emerging from the laser) at an exposed edge of the joining material. The entire unaccessible (i.e., sandwiched between two metal pieces) layer of joining material, being self-sustaining, will react upon initiating a small portion thereof.

This technique of joining two metal pieces together, such as by laminating and low-temperature joining, permits the two pieces of metal to be joined without significant mass heating,

and the various advantages of the present invention accruing to avoiding significant mass heating will be attained.

TAPE DELIVERY SYSTEM

As discussed hereinabove, the joining material can be delivered as a powder, applied as a paste, sprayed as an aerosol, or applied as a tape to the joint of to-be-joined components.

Figure 11A illustrates a two-layer tape 1100 that is well-suited to performing field joining. The two-layer (two-part) tape 1100 has a first part 1102 formed of aluminum (or of a sacrificial carrier laced with nanoscale aluminum particles), and a second part 1104 having an oxidizing agent (such as peroxide).

Figure 11B shows a three-part tape 1120, having a first aluminum part 1122 (compare 1102); a second oxidizing agent part 1126 (compare 1104) and a third part 1124 of microcellular foam material laced with peroxide.

Although the invention has been illustrated and described in detail in the drawings and foregoing description, the same is to be considered as illustrative and not restrictive in character -it being understood that only preferred embodiments have been shown and described, and that all changes and modifications that come within the spirit of the invention are desired to be protected.

CLAIMS

What is claimed is:

1. Method of making nanoscale powders from a starting material, comprising:

decomposing a starting material into relatively small nanoscale particles using an energy source selected from the group consisting of laser energy, electric arc, flame or plasma, said energy source decomposing the source materials.

2. Method, according to claim 1, wherein:

the starting material is a target having a surface; and

the energy source is a laser directed at the surface of the target and having sufficient energy to ablate the target.

3. Method, according to claim 2, wherein:

the target is selected from the group consisting of carbonates, hydroxides, salts, oxides, metals, sulfates , chlorides, carbides, borides, nitrides, complexes, compounds, composites, and their mixtures.

4. Method, according to claim 2, wherein:

the target is formed of calcium carbonate; and

the nanoscale powder is calcium oxide.

5. Method, according to claim 2, wherein:
the target is formed of aluminum hydroxide; and
the nanoscale powder is aluminum oxide.

6. Method, according to claim 2, wherein:
the target is formed of a magnesium compound; and
the nanoscale powder is magnesium oxide.

7. Method, according to claim 2, wherein:
the target is formed of a metal, alloy or mixture.

8. Method, according to claim 7, wherein:
the metal is selected from the group consisting of gold, copper and zinc, and other metals.

9. Method, according to claim 2, further comprising:
flowing a reactive gas across the surface of the target while ablating the target.

10. Method, according to claim 2, further comprising:
flowing a carrier gas across the surface of the target to convey ablated material from the surface of the target; and
separating relatively large particles in the ablated material from the relatively small nanoscale powders in the ablated material.

11. Method, according to claim 1, further comprising: cooling the nanoscale powders to prevent their agglomeration.

12. Method according to claim 1, wherein: the starting material is relatively-large particles; and

the energy source is an electric arc discharged through the relatively-large particles and having sufficient energy to decompose the relatively-large particles.

13. Method, according to claim 12, further comprising: conveying the relatively-large particles along a path defined by a conductive conveyor belt, said conductive conveyor belt acting as one of two electrodes of a spark gap.

14. Method, according to claim 12, further comprising: conveying the relatively-large particles along a path defined by a first conductive conveyor belt in a gap between the first conductive conveyor belt and a second conductive conveyor belt, said first and second conductive conveyor belts acting as two electrodes of a spark gap.

15. Method, according to claim 1, wherein the source material is relatively-large particles, further comprising:

conveying the relatively-large particles through a

nozzle having a tip;

causing a flame to be present at the tip of the nozzle, said flame being of a sufficient temperature to decompose the relatively-large particles into nanoscale powders; and

collecting the nanoscale powders.

16. Method, according to claim 1, wherein the source material is relatively-large particles, further comprising:

conveying the relatively-large particles through a nozzle having a tip;

causing a plasma to be present at the tip of the nozzle, said plasma being of a sufficient temperature to decompose the relatively-large particles into nanoscale powders; and

collecting the nanoscale powders.

17. Method, according to claim 16, further comprising:

introducing a heat-transfer medium at the tip.

18. Method, according to claim 16, wherein:

the plasma is caused by an energy source selected from the group comprising electric arc, laser, microwave, RF, filament, x-rays and neutrons.

19. Method of making nanoscale particles, comprising:

decomposing a starting material into nanoscale particles using an energy source to decompose said material and a coolant mechanism to trap said nanoparticles.

20. Method of making nanoscale particles selected from the group consisting of CaO, MgO, TiO_2, VO_2, Al_2O_3, FeO, Fe_2O_3, Fe_3O_4, SiO_2, Y_2O_3, Au, Cu, Zn, Sn, Pb, Ag, Si, Cr, Co, Fe, BN, TiN and other nitrides, borides, ZnS and other sulfides, hydroxides, SiC, WC and other carbides, fur use in applications selected from the group consisting of painting, coating, joining, bonding, brazing, soldering and welding, comprising:

decomposing a starting material into nanoscale particles using an energy source to decompose said material and, if the nanoscale particles tend to agglomerate, employing a coolant mechanism to trap said nanoparticles.

21. Self-sustaining joining material comprising:

at least a portion, by weight, of nanoscale size particles of an exothermic material.

22. Self-sustaining joining material, according to claim 21, wherein:

the exothermic material is aluminum.

23. Self-sustaining joining material, according to claim 21, wherein:

the exothermic material is magnesium.

24. Self-sustaining joining material, according to claim 21, wherein:

the joining material contains nanoscale size particles of aluminum and of magnesium.

25. Self-sustaining joining material, according to claim 21, wherein:

the joining material contains 18% magnesium of nanoscale particle size.

26. Self-sustaining joining material, according to claim 21, wherein:

the joining material comprises 15% aluminum of nanoscale particle size.

27. Self-sustaining joining material, according to claim 21, wherein:

the joining material contains the following amounts of the following materials having the following particle sizes: 2% Cerium (<1μm); 3% Boron (<1μm); 5% Chromium (<1μm); 12% Nickel (<1μm); 18% Magnesium (<1μm); 15% Aluminum (nanoscale); 2% Tin (1-3μm); 5% Zinc (1-3μm); 20% Copper (1-3μm); and 18% Silver (1-3μm).

28. Joining material, comprising nanoscale size particles selected from the group consisting of gold, cadmium, copper, zinc, tin, lead, silver, silicon, chromium, cobalt, antimony, bismuth, aluminum, iron, magnesium, nitrogen, carbon, boron, and alloys and composites of these materials.

29. Method of joining components together, comprising:

positioning a one component adjacent an other component;

applying a joining material to at least one junction between the one component and the other component; and

directing an energy source at the joining material.

30. Method, according to claim 29, wherein:

the joining material is self-sustaining.

31. Method, according to claim 29, wherein:

the energy source is a laser.

32. Method, according to claim 31, wherein:

the laser is an Nd:YAG laser.

33. Method, according to claim 31, wherein:

the laser provides a beam having a cross-sectional linear dimension of less than three millimeters.

34. Method, according to claim 33, wherein the cross-sectional dimension of the beam is between two and three millimeters.

35. Method, according to claim 29, wherein:

the energy source is selected from the group of energy sources consisting of flame, arc, plasma and spark.

36. Method, according to claim 29, wherein the energy source is a laser providing a beam, and further comprising:

walking the beam along the at least one junction between the one component and the other component.

37. Method, according to claim 29, wherein the energy source is a laser providing a beam, and further comprising:

walking the beam along the at least one junction between the one component and the other component after previously applying the nanoscale joining material to the at least one junction between the one component and the other component.

38. Method, according to claim 29, wherein the energy source is a laser providing a beam, and further comprising:

walking the beam along the at least one junction between the one component and the other component while simultaneously applying the nanoscale joining material to the at least one junction between the one component and the other

component.

39. Method, according to claim 29, wherein:

the one and the other components are steel.

40. Method, according to claim 29, wherein:

the energy source elevates the temperature of the joining material by no more than 400°C.

41. Method, according to claim 29, wherein the energy source is a laser providing a beam, the joining material is provided in the form of a powder, and further comprising:

providing the beam through an opening of an annular nozzle body;

providing the powder from at least one output orifice of the nozzle body; and

directing the beam and the powder at a common point.

42. Method, according to claim 41, further comprising:

moving the nozzle along the junction between the one component and the other component.

43. Automatic transmission bowl assembly comprising:

a bowl having an inner surface;

a plurality of vanes, each having an inner edge and an outer edge with a length, each vane disposed to have its outer edge against the inner surface of the bowl; and

joining material extending substantially the full length of the outer edge of the vane and joining the vane to the bowl.

44. Automatic transmission bowl assembly, according to claim 43, wherein:

the bowl component is an impeller bowl.

45. Automatic transmission bowl assembly, according to claim 43, wherein:

the bowl component is a turbine bowl.

46. Automatic transmission bowl assembly, according to claim 43, further comprising:

joining material joining the inner edges of the vanes to a shroud.

47. Automatic transmission bowl assembly, according to claim 43, wherein:

the joining material includes nanoscale elements.

48. Automatic transmission bowl assembly, according to claim 43, wherein:

the joining material is self-sustaining.

49. Automatic transmission bowl component, comprising:

a bowl having an inner surface;

a plurality of vanes joined by their outer edges to the inner surface of the bowl, each vane formed as a hollow member.

50. Automatic transmission fluid coupling, comprising:

an impeller bowl;

a turbine bowl opposing the impeller bowl;

a plurality of first vanes, secured by their outer edges to the impeller bowl;

a plurality of second vanes, secured by their outer edges to the turbine bowl; and

a stator disposed between the impeller bowl and the turbine bowl, between the first vanes and the second vanes, and extending radially to at least a radial midpoint of the vanes.

51. Automatic transmission fluid coupling, according to claim 50, further comprising:

an annular ring disposed on a peripheral edge of the stator for the purpose of supplanting a torus ring attached to the vanes.

52. Automatic transmission fluid coupling, according to claim 50, further comprising:

a flat disc-like extension extending radially from a peripheral edge of the stator.

53. Tape, comprising:

a first layer comprising aluminum; and

a second layer comprising an oxidizing agent.

Figure 1

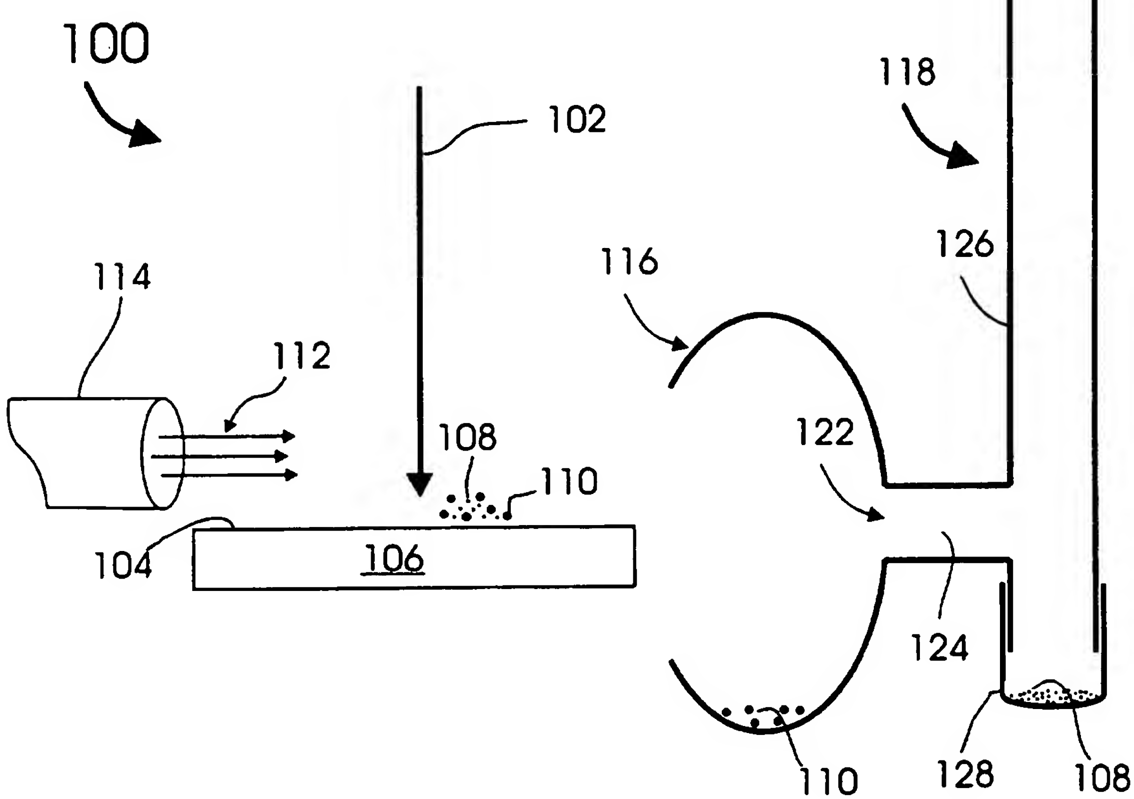
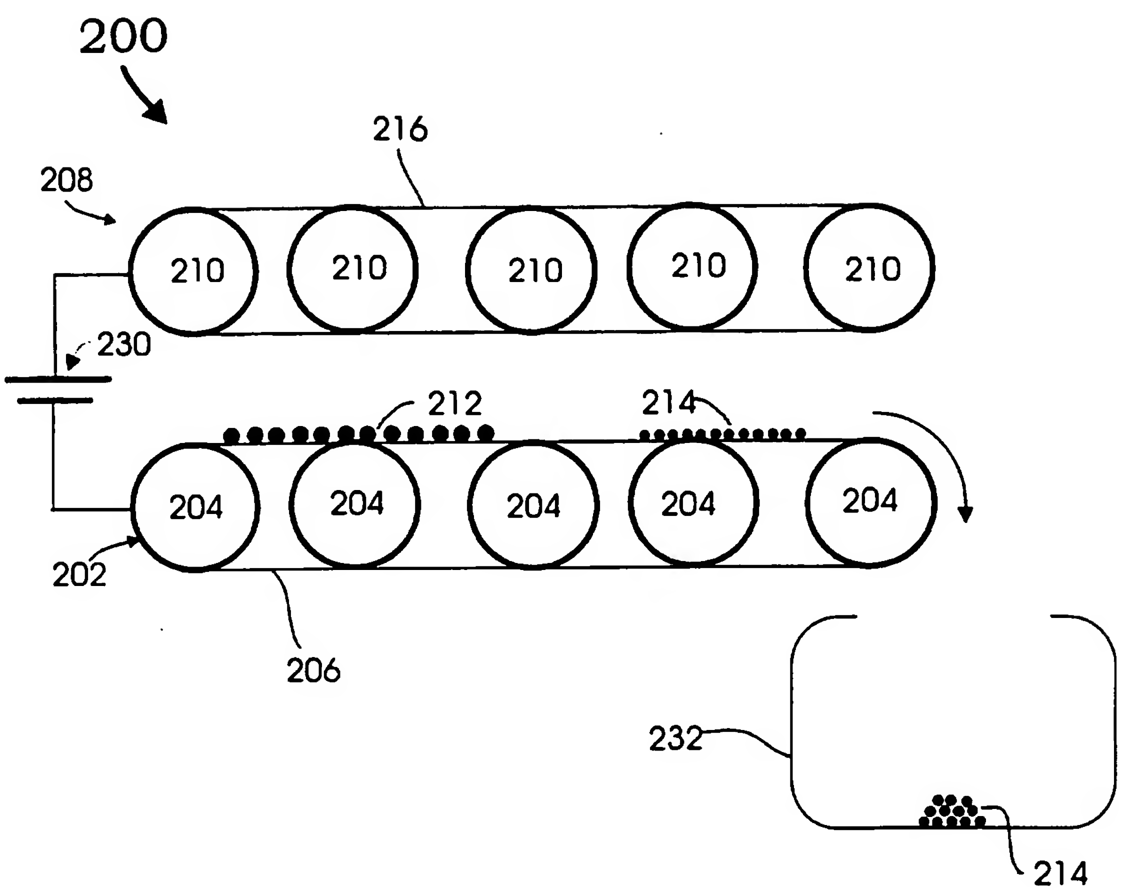


Figure 2A


200
216
208
210
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210
210
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230
212
214
204
204
204
204
204
202
206
232
214

Figure 2B

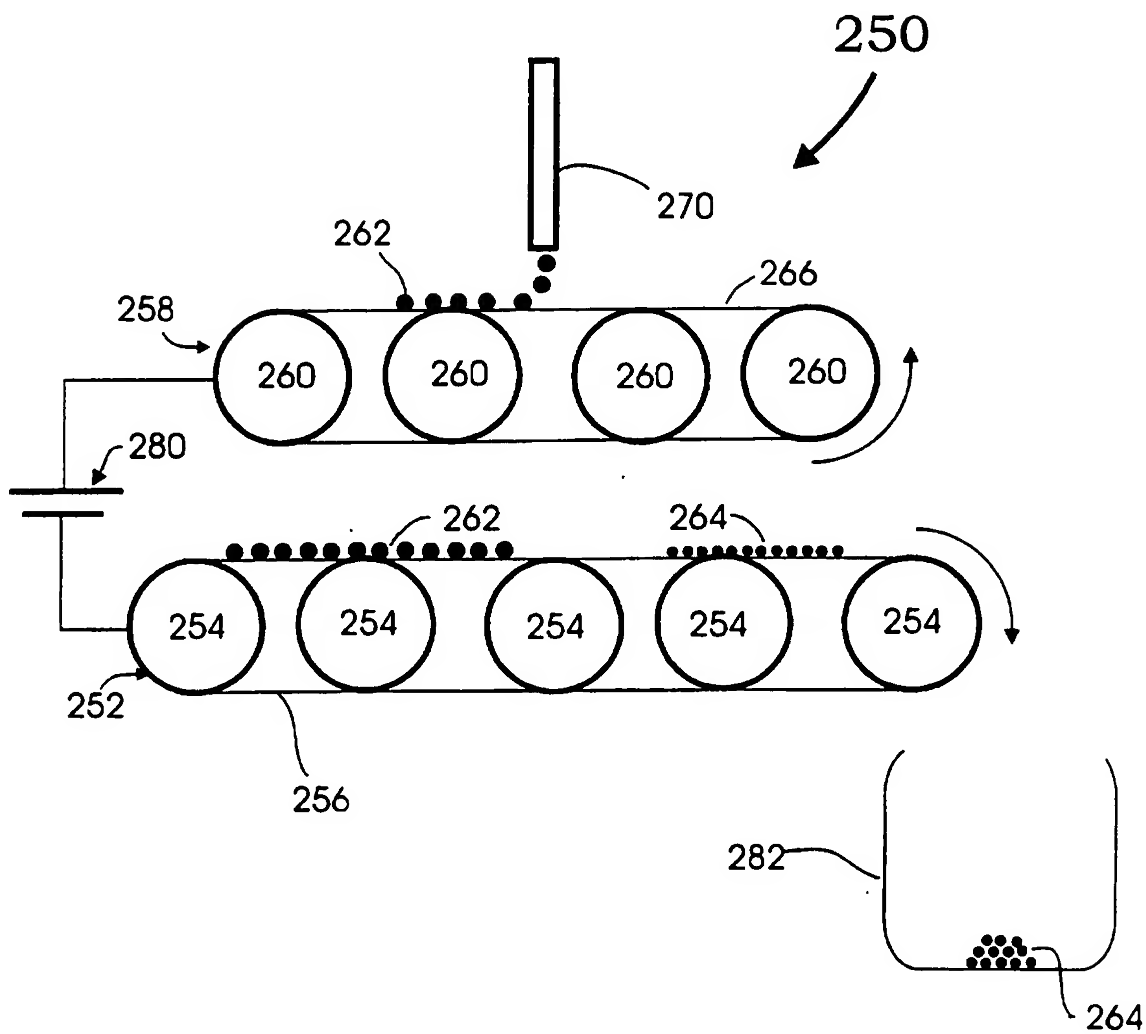

250
270
262
266
258
260
260
260
260
280
262
264
254
254
254
254
254
252
256
282
264

Figure 3A

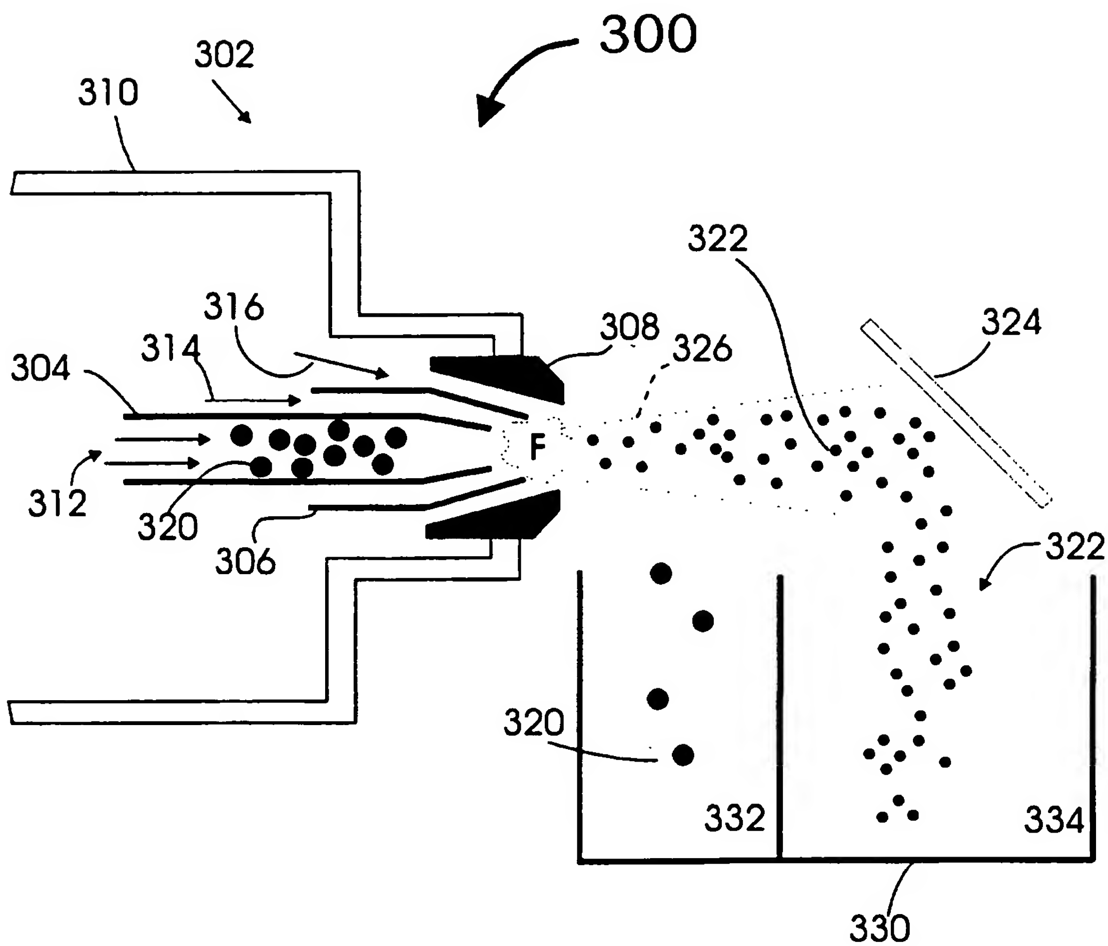
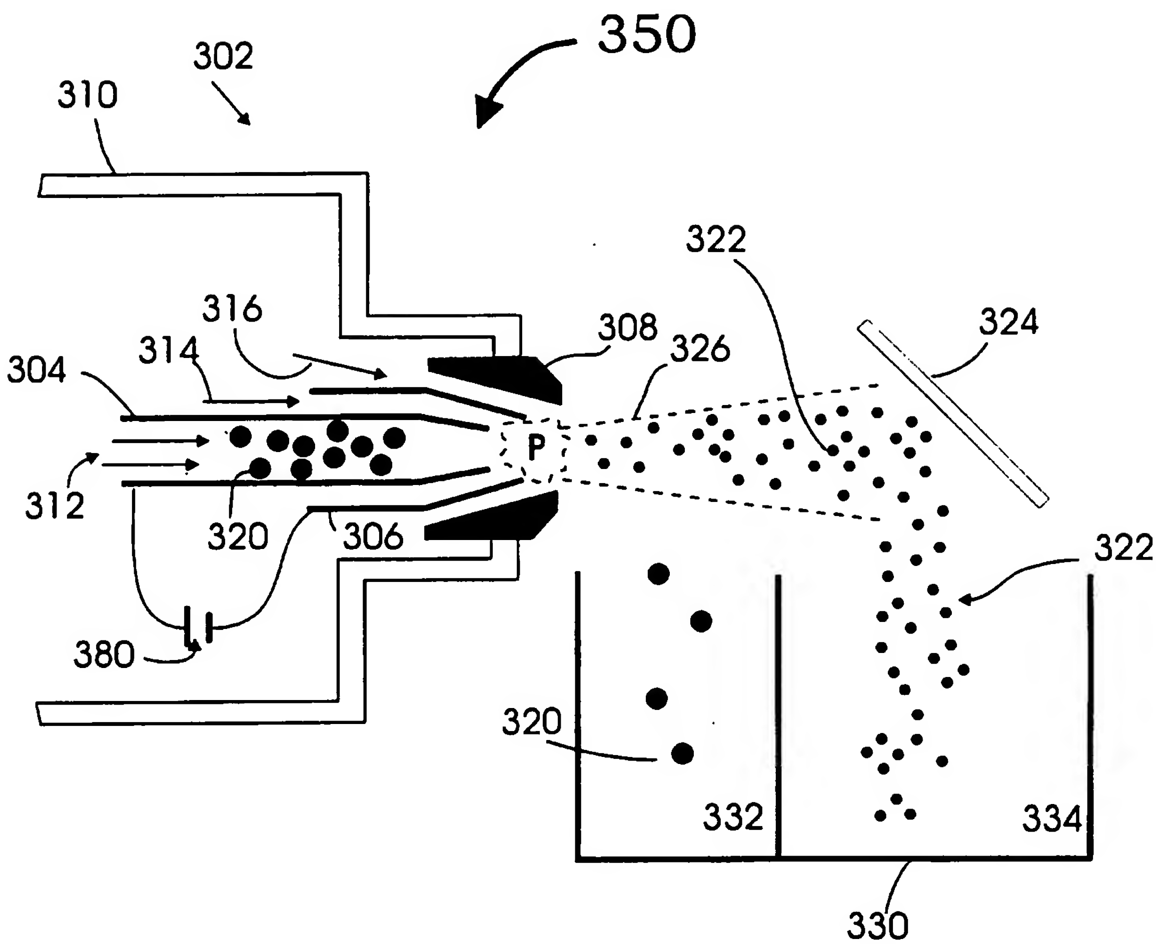

300
302
310
316
314
304
312
320
306
308
326
F
322
324
322
320
332
334
330

Figure 3B


350
302
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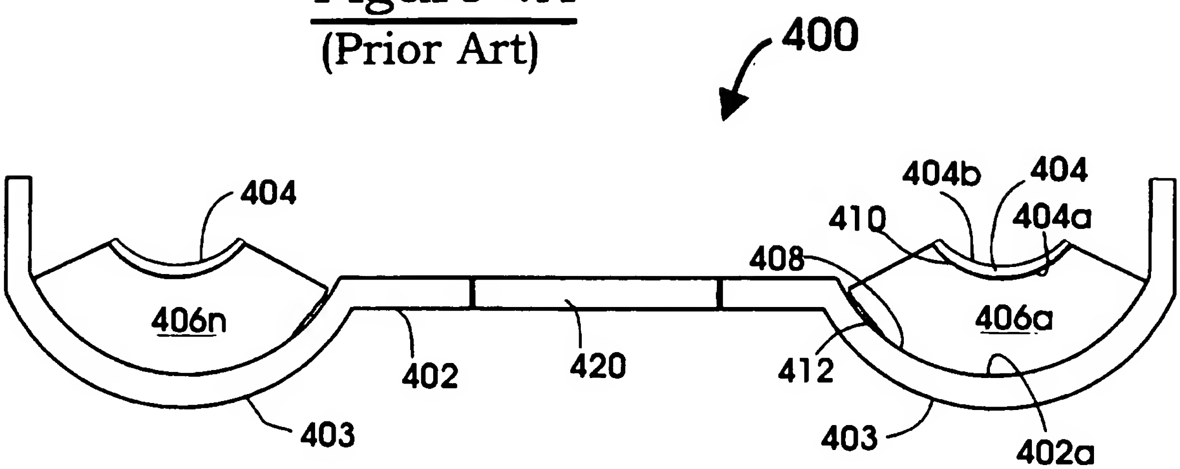
330

Figure 4A
(Prior Art)



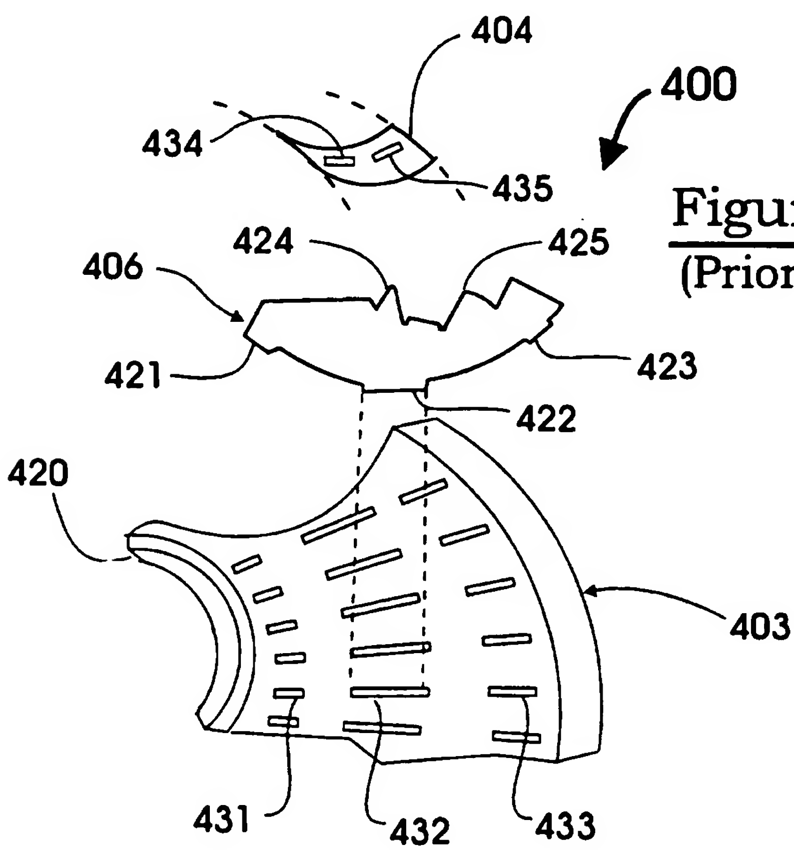


Figure 4B
(Prior Art)

Figure 5A

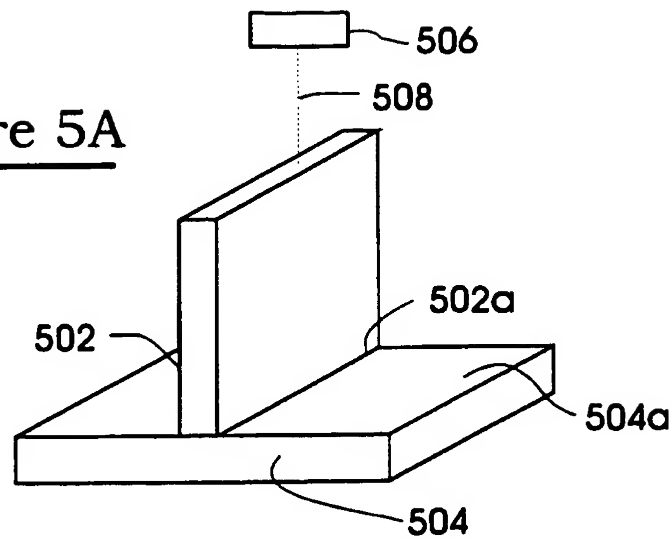


Figure 5B

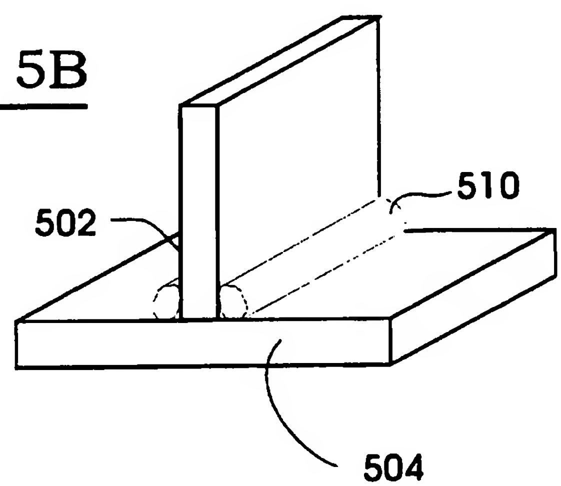


Figure 5C

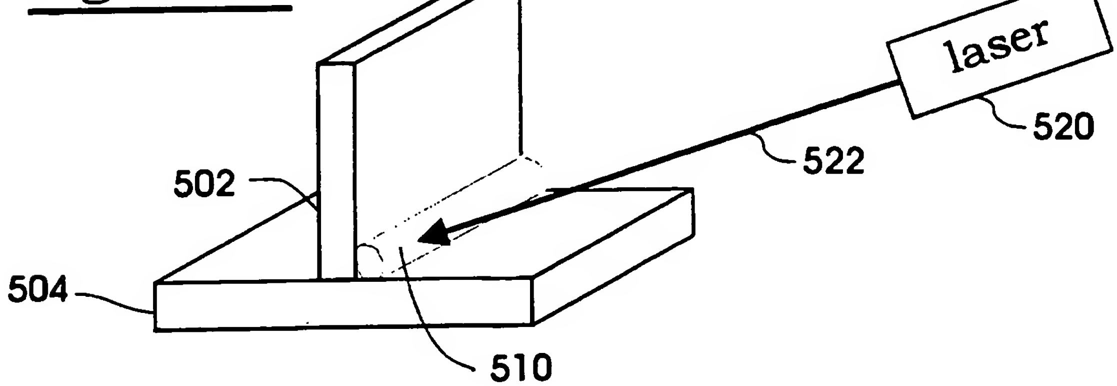


Figure 6

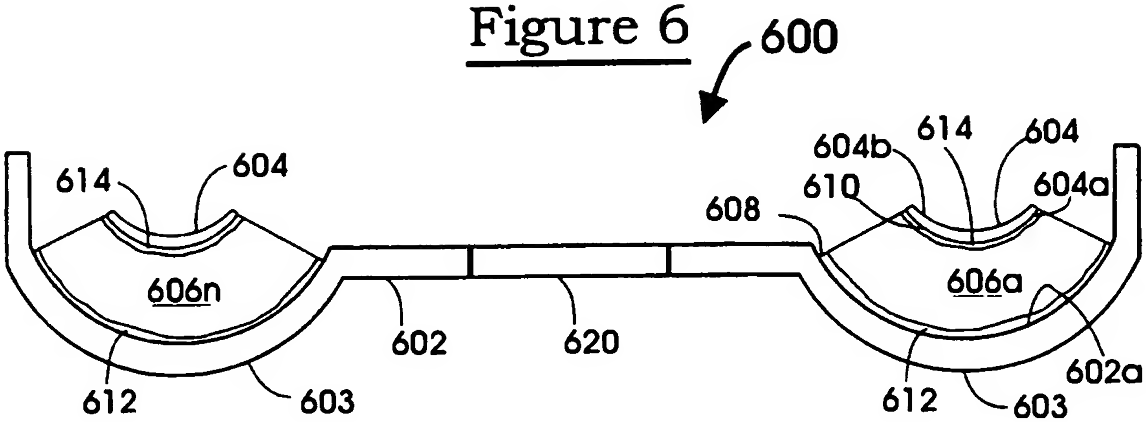
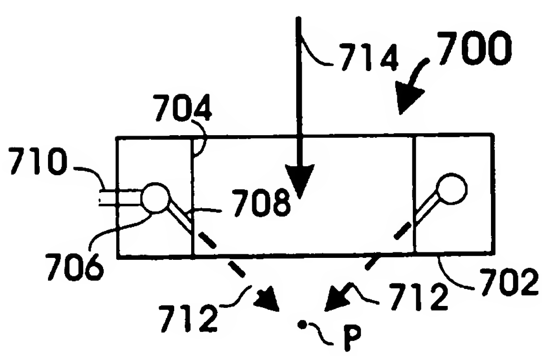


Figure 7A

Figure 7



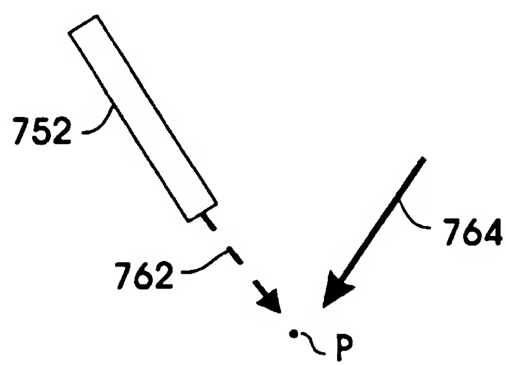


Figure 8A

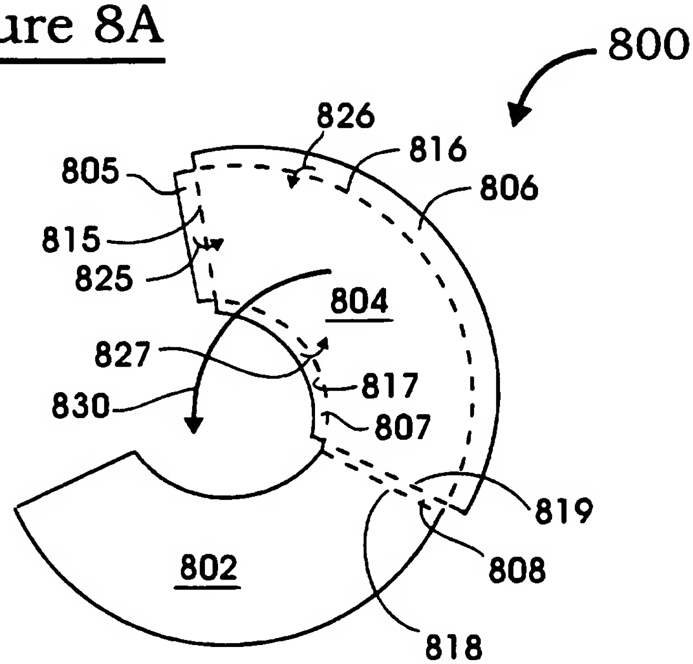


Figure 8B

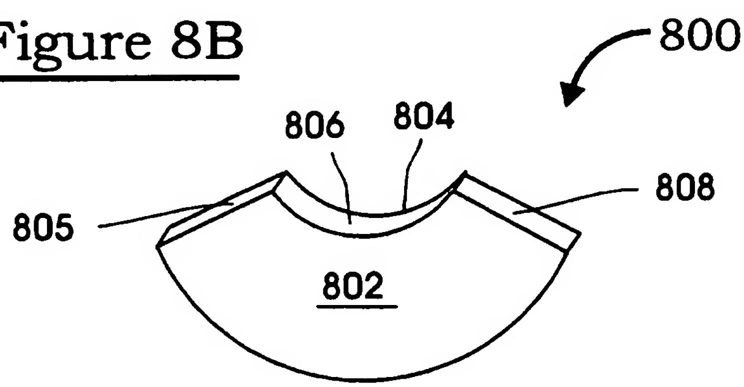


Figure 8C

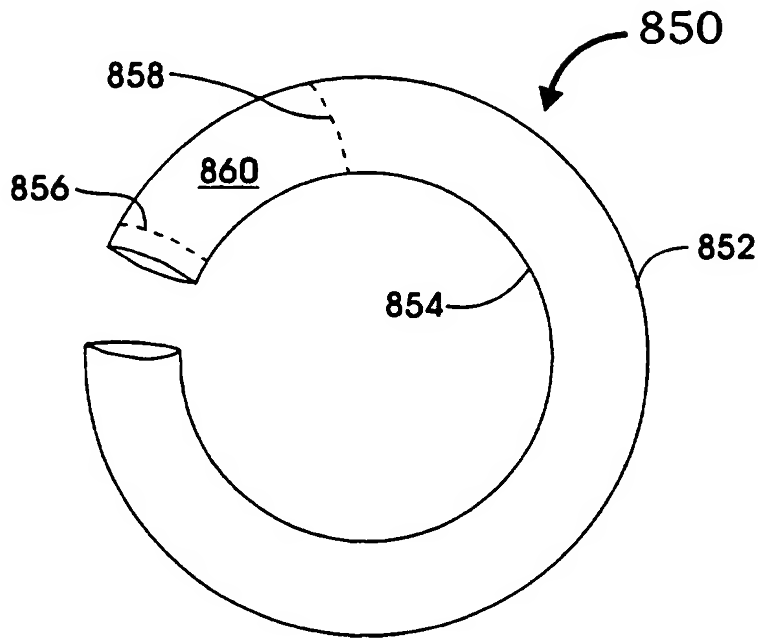


Figure 8D

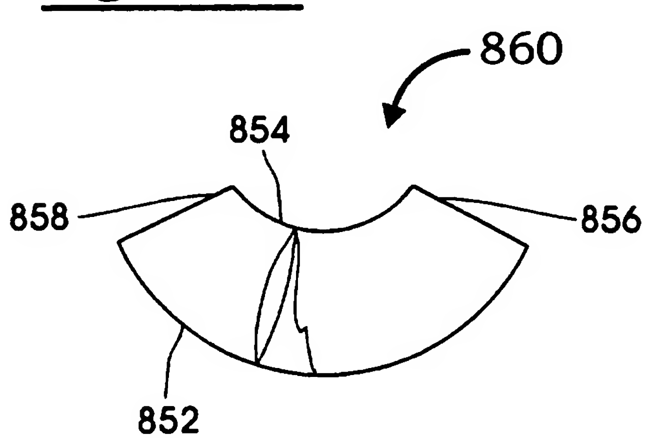


Figure 9
(Prior Art)

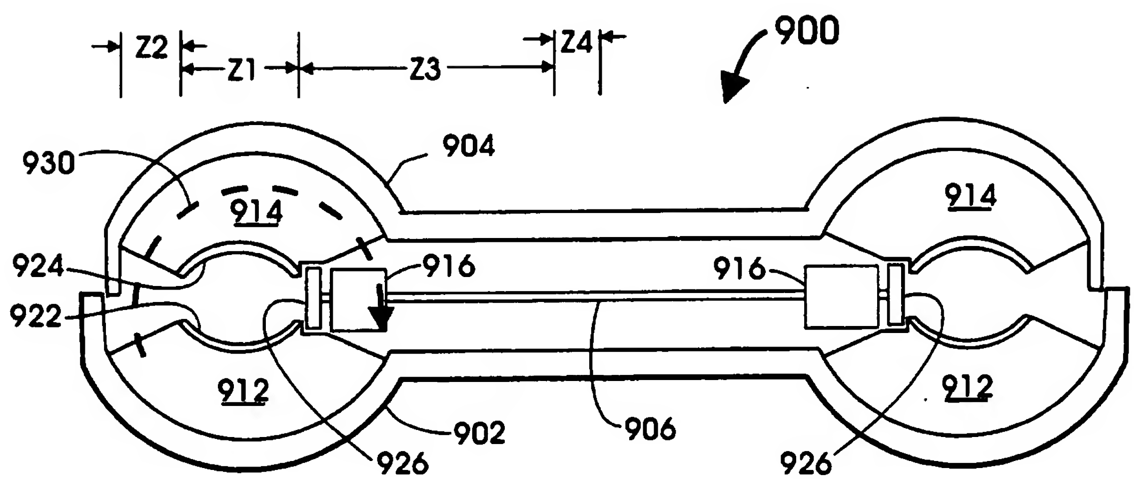


Figure 9A

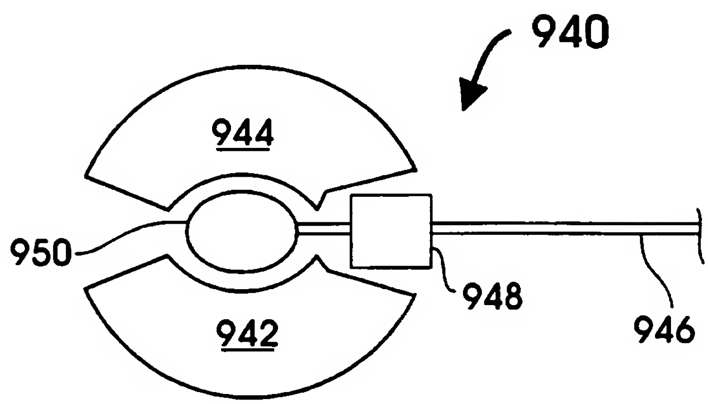


Figure 9B

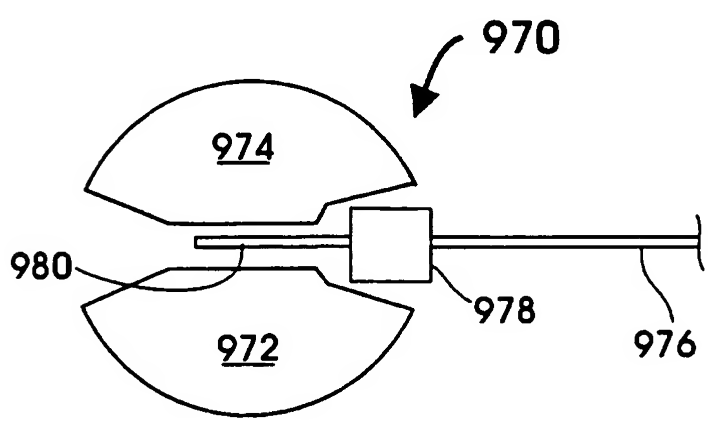


Figure 10A

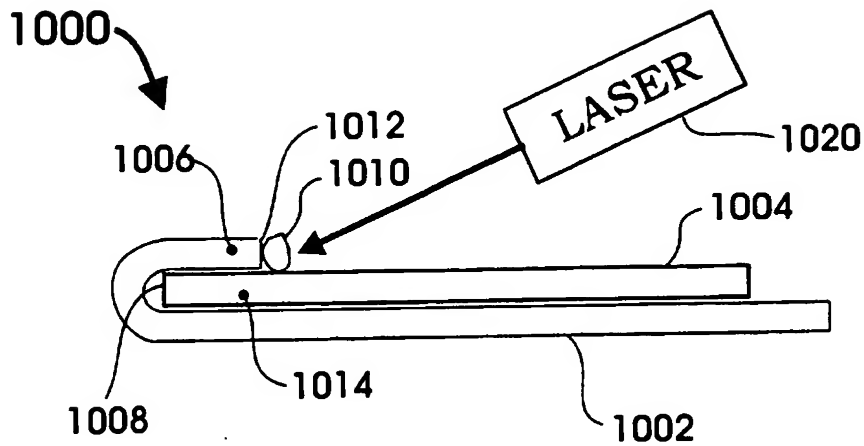


Figure 10B

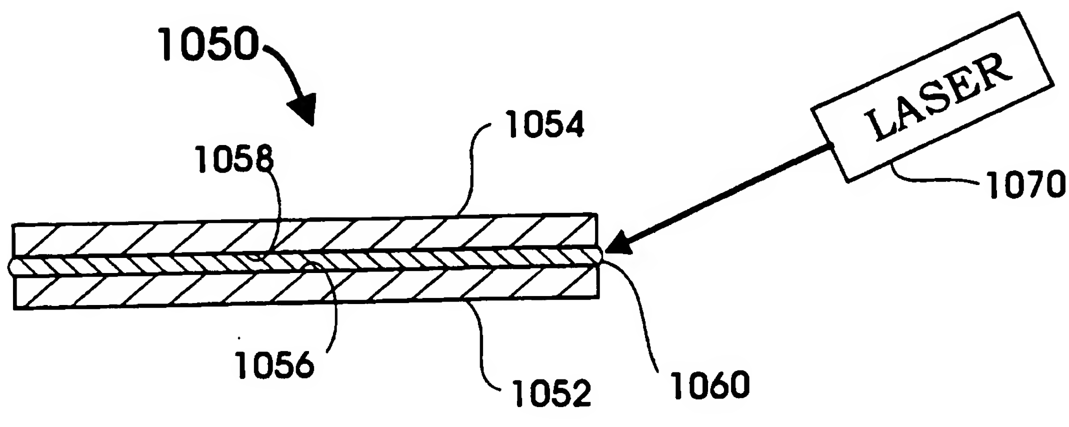


Figure 11A

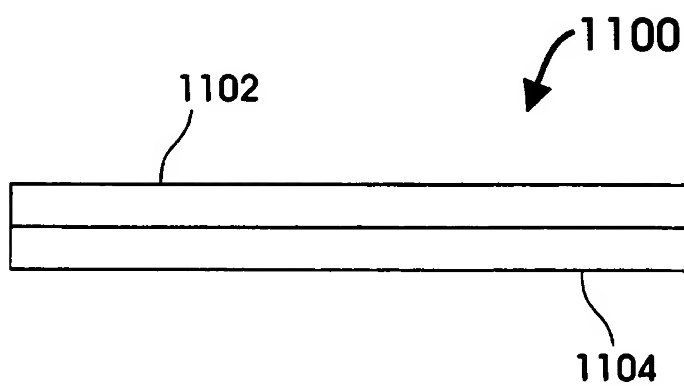


Figure 11B